AMERICAN INSTITUTE FOR STRATEGIC COOPERATION

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SECTION I: INTRODUCTION

Two recent world events---the breakup of the Soviet Union and the 1991 Gulf War---have shifted the focus of defense planning away from large-scale conflict in Central Europe and toward lesser-sized conflicts in other parts of the world. This shift has highlighted the importance of nonproliferation policies aimed at curbing the spread of various weapons systems which are difficult to counter and can cause large-scale damage.

Ballistic missiles are one such weapons system. They have a number of characteristics which make them of particular nonproliferation concern. They travel with great speed which makes them ideal for preemptive or suppressive attacks. In addition their speed makes it very difficult to intercept them with active defenses. When used to attack large cities, their psychological effects appear to be more severe than those caused by aircraft attacks. The reasons for this are complex but appear to result from a combination of factors including the ability to use ballistic missiles to conduct prolonged, harassing attacks; the difficulty of defending against these attacks; the fact that such attacks can occur with little or no warning; and, the impersonal nature of the attacking force. Ballistic missiles also do not need to operate from large fixed facilities such as airfields, rather they are well-suited to mobile operations which make it difficult to suppress them with counterstrikes. In addition, ballistic missiles have the advantage of not requiring skilled pilots--a resource difficult for many Third World countries to obtain. Moreover, even the human pilots of First World countries are affected by defenses in ways that ballistic missiles are not. In the face of strong defenses, the fear of being shot down can make aircraft attacks ineffective--an effect that has been demonstrated historically on a number of occasions.

Most of the advantages of ballistic missiles also apply to cruise missiles. However, while cruise missiles, unlike ballistic missiles, are vulnerable to anti-aircraft defenses, they have the advantage of being far less expensive than ballistic missiles and they rely on more commonplace aircraft technology. Up to now little use has been made of cruise missiles in the Third World, but many countries now have embarked on cruise missile development programs and the prospect of being able to use Global Positioning System (GPS) guidance on cruise missiles makes the threat quite serious.

Whereas the need to limit the spread of nuclear weapons has existed since the discovery of nuclear fission, the need to curb the spread of missile technology is much more recent. Ten years ago missile proliferation was of little concern. Since then a number of Third World countries have initiated ballistic missile development programs which have made great strides, partly due to technology acquired from the industrialized countries. In 1987, in response to this spread of technology, seven Western economic allies formed the Missile Technology Control Regime (MTCR) with their announcement that each was adopting a set of identical policies to be implemented by their governments individually.[1] By January 1992 the membership had grown to 18 members.[2] In addition, Israel and Switzerland have pledged that they will follow the MTCR guidelines even though they are not formal members. The MTCR aims to limit the proliferation of missiles capable of delivering a warhead of at least 500 kg to 300 km.

The MTCR, however, is neither an international treaty nor an international body; rather, it is a way of coordinating policies of the member countries through the exchange of information and the adoption of common guidelines. The MTCR has been only somewhat successful. The fact that some member countries have not been willing to make the hard political decisions necessary to completely halt exports of missile technology and that some major players in the proliferation field are not members of the MTCR has qualified its successes. In early 1990 the former Soviet Union committed itself to adopting the MTCR guidelines (similar to the position of Israel and Switzerland), but with the recent demise of the Soviet Union, the policies of the former Republics of the Soviet Union are less clear.[3] The position of China also has not been resolved. [4]

The Gulf War demonstrated that the MTCR's concerns about missile proliferation were justified. Iraq's large, well equipped and battle-tested army was disposed of with surprising ease. Its modern air

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1. The seven original members were Canada, France, The Federal Republic of Germany, Italy, Japan, the United Kingdom, and the United States.

2. The eleven newer members are Australia, Austria, Belgium, Denmark, Finland, Luxembourg, the Netherlands, Norway, New Zealand, Spain, and Sweden.

3. The recent announcement that Russia is negotiating with India on the sale of oxygen/hydrogen fueled rocket technology is not an encouraging development. See *Aviation Week & Space Technology*, April 27, 1992, p. 11.

4. China has recently said that it will abide by the restrictions of the MTCR but it is unclear whether China will actually stop selling missiles to Pakistan, Syria and Iran. See Jim Mann, "U.S. Lifting Sanctions on China Sales," *Los Angeles Times*, February 22, 1992, p. A1.

force flew almost no combat sorties and wound up fleeing to Iran. In contrast, Iraq's long-range missiles proved to be impossible to suppress and it Iraq managed to use them in such a way so as to make their suppression politically and, thereby, militarily important. Despite the United Nation's resolutions, in a few years Iraq may again pose a missile threat to the region.[5] An examination of Iraq's missile program and the results of its attacks during the Gulf War is critical to understanding what the nature of this renewed threat might be. In addition, since the characteristics of Iraq's missiles are typical of those in other Third World countries, this examination is intended to provide a broad understanding of the threat posed by missile programs in other parts of the world as well.

To place the lessons of the Gulf War in perspective, the next section, Section II, examines in general terms how the technical characteristics of ballistic missiles limit the types of targets that can be attacked effectively. To support this assessment, two examples of the employment of ballistic missiles are chronicled. The German *V-2* attacks on London during World War II are reviewed in Section III. The British accounts of the missile damage inflicted on London as well as the availability of German war records make it the best documented use of ballistic missiles. Section IV looks at the use of ballistic missiles by Iraq and Iran during their eight-year (1980-1988) war.

The following section, Section V, chronicles the Iraqi ballistic missile attacks during the Gulf War, with particular emphasis on factors such as the rate of missile fire and Iraq's targeting strategy. The manner in which Iraq used its missiles enables conclusions to be drawn about Iraqi missile ranges and CEPs.[6] This section also examines what Iraq accomplished with its attacks, and the Coalition's[7] difficulties in suppressing them. The Gulf War was the first time that defenses (in the form of the *Patriot* antimissile system) were used in combat against ballistic missiles. The effectiveness of the *Patriot*, including post-war assertions that the defenses actually led to an increase in damage, is also analyzed.

The problem of missile proliferation is not static. The missiles used during the Gulf War had a

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5. For example, more than one year after the end of the Gulf War, CIA Director Robert Gates has said that Iraq still retains hundreds of "Scud" missiles. See John M. Broder, "Hussein Losing His Grip, but Alternative Might Be More of Same, CIA Chief Says," *Los Angeles Times*, March 28, 1992, p. A8.

6. Circular Error Probable (CEP) is a measure of missile accuracy.

7. The principal members of the Coalition were Egypt, France, the Kuwaiti Forces-in-Exile, Saudi Arabia, Syria, the United Kingdom and the United States.

unitary high explosive warhead, a range of 600-650 km and a CEP of roughly 2 km. Iraq, before the war, and many countries today still are trying to substantially improve their missiles by increasing their range, increasing their accuracy and equipping them with more lethal warheads such as nuclear, chemical or advanced conventional. Section VI's examination of these efforts reveals the full extent of the missile proliferation problem.

It might be reasonable to assume that the Gulf War has amply demonstrated the problems associated with missile proliferation. But there still remains a school of thought that believes missile proliferation is an overrated problem and that the spread of attack aircraft poses a more serious threat. This viewpoint is critically examined in Section VII. An important part of this analysis demonstrates that there are many occasions when air defenses can achieve a greater-than-ten-percent attrition rate and that such defenses can prevent aircraft from effectively attacking their targets.

Finally a summary and conclusions are presented in Section VIII.

SECTION II:
TARGETS FOR BALLISTIC MISSILE ATTACKS

Reportedly Iraq has had or has been developing, at one time or another, seven different types of missiles. Brief histories of these reports as well as the technical characteristics of these missiles are contained in Appendix I. As will be shown below, it is likely that virtually all of the missiles used during the Gulf War were *Al-Husayns*, each with a range of 600-650 km, a CEP of about 2 km, and a 300-500 kilogram unitary high-explosive warhead. These characteristics are typical of most of the ballistic missiles likely to be in the possession of Third World countries now or in the near future.

Given these technical characteristics, what types of targets can be attacked effectively? The equivalent lethal radius of a unitary high-explosive warhead is in the low tens-of-meters range. For example, when used against London during World War II, the equivalent lethal radius of the 1,000 kg warhead of the German *V-2* missile was about 20 meters, which resulted in a lethal area of about 0.001 square kilometers (about one-quarter acre).[1] A 2 km CEP means that half of any successfully-fired missiles would land within an area of 12.6 square kilometers. Therefore, a missile with a 1,000 kg warhead and a 2 km CEP would only have about one chance in twenty thousand of destroying any given point target. Therefore, this type of missile can only be used against a sufficiently large target that the missile has a reasonable chance of hitting some portion of it. Such likely targets, however, must have their significant elements distributed over their entire area so that any missile which hits the target area will destroy some small part of it. Only a few targets, including cities and airfields, have such characteristics. The effectiveness of attacks on these and other likely targets is discussed below.

CITIES

Cities, which can cover over 1,000 square kilometers and have population distributed over their entire area, have been the most frequent target for ballistic missiles with a greater than 1 km CEP and a

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1. The equivalent lethal area is calculated by dividing the average number of people killed per missile landing in the LCDR by the average population density of London.

unitary high-explosive warhead. To be suitable for missile attack, a city should have an area, roughly circular in shape, at least comparable to the missile's CEP. Otherwise too many missiles will fall outside the city, in open country. Also, the greater the population density the more people will be killed by each missile. Since World War II many Third World cities have experienced explosive population growth and their population densities are much higher than any city in the United States; yet, as will be shown below, even a heavy missile bombardment on a city will not kill that many people or destroy that many structures. Certainly the World War II fire bombing was far more destructive and deadly but the psychological effects from missile attacks can be far more severe than those from much heavier aircraft bombing raids. These effects seem to result from the lack of warning of missile attacks, the fact that missiles can strike at any time, around-the-clock, for extended periods, the difficulty of defending against missile attack, and the impersonal nature of the attack.

AIRFIELDS

Airfields, which are large fixed targets, are one of the few other target classes that can be attacked by a ballistic missile with a greater than 1 km CEP and a unitary high-explosive warhead. On a major airfield, the main runways are 3-4 km in length and, with hangers and other support facilities, an airfield can cover over 5 square km.[2] However, even with this size target, the probability of a hit is sensitive to the CEP. With a 2 km CEP, the chance of a hit is only about 24 percent. Furthermore, since about half of the area of the airfield is empty space (ground between runways and taxiways, etc.), only about half of the missiles falling on an airfield will actually damage some portion of it. Given the rates of fire managed by Iraq in the Iran-Iraq and Gulf wars (a maximum of 10-15 per day), it is likely there would only be one or two damaging hits per day. Clearly this level of fire would be viewed only as an harassing tactic not seriously interfering with airfield operations. At most, such attacks might cause an airfield to shutdown briefly to evaluate the level of damage; one might try to take advantage with a follow-up attack of aircraft hitting these airfields during their downtime.

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2. Diagrams of a number of airfields can be found in various DOD Flight Information Publications (Terminal) published by the Defense Mapping Agency Aerospace Center, St. Louis, Missouri.

OIL FACILITIES

One obvious concern about missile proliferation in the Mideast is the vulnerability of oil-producing facilities to missile attack. Oil wells and pipelines are very hard to hit; wells are small and dispersed and pipelines, while long, are not very wide. The facilities, designed to avoid the day-to-day danger of explosion and fire, are constructed in such a way that damage from a lucky hit could be quickly isolated and repaired, with little loss of production. Oil refineries are better targets. For example, a typical large refinery such as Chevron oil refinery in El Segundo, California, covers an area of approximately 4 square kilometers.[3] A missile with a 2 km CEP would have about a 20 percent chance of striking somewhere within the refinery area. About three-quarters of the refinery area is oil storage tanks. A hit on these tanks might cause a fire but it would do little to interfere with the operation of the plant. The chance of a missile hitting the refinery's processing area would be just a few percent. Experiences from World War II have shown that even hundreds of bomb hits would shut down a refinery for only four to six weeks.[4] Only if a critical piece of equipment--such as the primary distillation towers--were struck would the refinery be knocked out for a longer period of time, perhaps a year. The chance of this happening as the result of a few missile strikes is very small.

GROUND FORCES

Ground forces are a logical target in any military conflict but here, too, missile attacks against them are not very profitable. Since troops are mobile it may be difficult to direct an attack against them before they relocate. Even if they can be targeted, a typical troop concentration large enough to be targetable (brigade or larger) has a density of only about a few hundred persons per square kilometer. Most likely a missile landing in such a concentration most likely would not kill anyone. This result is not surprising since troops must be concerned with artillery fire, and any troops concentrated enough to be affected by long-range missiles would first be devastated by artillery.

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3. Aerial photograph of the refinery obtained from I. K. Curtis Services Inc., Burbank, California.

4. United States Strategic Bombing Survey,*Rhenania Ossag Mineraloelwerke,* A G Harburg Refinery Hamburg, Germany, #119 (Oil Division, January 1947).

OTHER SINGLE INSTALLATIONS

Even large single-point targets (for example, the Pentagon in Washington, D.C., or the Rose Bowl in Pasadena, California) are too small to be usefully attacked by a missile with a 2 km CEP because such facilities cover areas of a few tenths of a square km or less. This type of missile would have only a one percent or less chance of hitting such a target. This will be discussed in more detail with reference to Iraq's attacks on Israel's Dimona nuclear reactor during the Gulf War.

SECTION III:
BALLISTIC MISSILE USE DURING WORLD WAR II

The German *V-2* bombardment of London during World War II was the first significant military use of long-range ballistic missiles.[1] The *V-2* missile had a range of about 330 km, a 1,000 kg warhead and a CEP of 17.7 km (as determined by analysis of its actual performance).[2] Between September 8, 1944 and March 27, 1945, 1,359 *V-2s* were launched against London, of which 1,054 (78 percent) actually struck somewhere within the United Kingdom.[3] Of these, 517 landed inside the 1,890 sq km area of the London Civil Defense Region (LCDR--approximately Greater London). These 517 missiles killed about 2,480 people, or approximately 4.8 persons per missile.[4] While this was the average, the distribution was quite skewed. Three missiles killed over 100 people each and the top five hits (about one percent) caused about 21 percent of the fatalities.[5].

The LCDR was roughly circular, with a radius of about 24.5 km.[6] Given the *V-2*'s CEP of 17.7 km, one would have expected around 73 percent of the missiles to strike within the LCDR but, in fact, only 49 percent of the missiles which reached the United Kingdom actually struck the LCDR. Two reasons accounted for this. First, the aim point appears to have been biased, so that the center of the impact

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1. The Germans used the *V-2* to attack a number of targets besides London and in particular fired over 1,600 V-2s at the Belgium city of Antwerp. Unfortunately the effects of these other attacks are not well documented.

2. The United States Strategic Bombing Survey, *V Weapons in London*, Report No. 152, Physical Damage Division, January 1947, pp. 8-10.

3. Basil Collier, *The Defence of the United Kingdom*, Her Majesty's Stationery Office, London, 1957, Appendix XLIX.

4. Fetter (Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction," *International Security*, Summer 1991, p.13) gives 2,754 killed making 5.3 killed per missile. However, 2,754 is the total number of fatalities in the United Kingdom, not London. See *Ibid*, Appendix L and The United States Strategic Bombing Survey, *op. cit.* p. 27.

5. These events were: November 25, 1944, Woolworths in Deptford, 160 killed; March 27, 1945, Hughes Mansions in Stepney, 134 killed; March 8, 1945, Smithfield Market, 110 killed; December 26, 1944, Islington, 68 killed; March 7, 1945, Folkestone Gardens in Deptford, 52 killed. The Hughes Mansions incident occurred on the last day of the*V-2* attacks. See Norman Longmate, *Hitler's Rockets*, Hutchinson & Co. Ltd, London, 1985. In Antwerp an even worse event occurred on December 16, 1944 when a *V-2* struck the Rex Cinema killing 271. See David Irving, *The Mare's Nest*, William Kimber, London, 1964, p. 294.

6. The United States Strategic Bombing Survey, *op. cit.*, p. 1.

points was in the eastern part of the LCDR. Second, some of the missiles that reached the United Kingdom had gross errors causing them to fall short. These two factors resulted in 378 missiles landing in the adjacent English county of Essex.

Since few cities are the size of the LCDR, attempts to attack smaller cities with a CEP as large as the *V-2* would not result in many successful strikes. For example, between September 25, 1944 and October 12, 1944 the Germans attacked Norwich in East Anglia, a city with a radius of about 2.0 km. Thirty-seven of the 43 *V-2*s launched landed in the rough vicinity of the city.[7] Each missile had only about a 0.9 percent chance of hitting Norwich, and there was only a 28 percent chance that even one of the 37 missiles would hit the city. This was borne out by actual experience: the closest missile impact was near the edge of Norwich, and despite 37 missile impacts, no one was killed and there was only one serious injury. It is not clear whether the townspeople even realized they were the target of that attack.

Anti-aircraft guns and fighter aircraft defenses were useless against the *V-2* because the missile traveled far too fast to be intercepted. The principal countermeasure attempted was fighter-bomber armed reconnaissance of the missile launch sites in Holland. Many thousands of sorties were flown. The results, however, were very meager--partly due to the inherent problems in attacking mobile targets, and partly due to Germany's use of launch sites near Dutch cities or in wooded areas.[8]

The psychological effects of the *V-2* rocket bombardment of London were more severe than the number of fatalities would otherwise suggest. It is useful here to compare the effects of the *V-2* ballistic missile with the *V-1* missile, which was a cruise missile launched from sites in northern France at London. The main part of the *V-1* offensive occurred in the three-month period from June 12, 1944 to September 5, 1944. During this time over 9,000 missiles were fired, of which 2,340 landed in the LCDR, killing more than 5,000 people.[9] This was far less than the 43,700 people killed during the attacks by manned aircraft during the nine months of the Blitz (September 1940-May 1941), yet British Prime Minister Winston Churchill thought that the psychological effects of the *V-1* might well have been worse.

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7. Basil Collier, *op. cit.*
8. *Ibid.*
9. *Ibid*, Appendices XLV and L.

"This new form of attack imposed upon the people of London a burden perhaps even heavier than the air-raids of 1940 and 1941. Suspense and strain were more prolonged. Dawn brought no relief, and cloud no comfort. The man going home in the evening never knew what he would find; his wife, alone all day or with the children, could not be certain of his safe return. The blind impersonal nature of the missile made the individual on the ground feel helpless. There was little that he could do, no human enemy that he could see shot down."[10]

The *V-1* had killed more than 5,000 people in about three months. The *V-2* would kill about half as many people in twice the amount of time (about 2,500 people in about six months), yet its psychological effects appear to have been worse than those of the *V-1*. This is the view of British writer Norman Longmate, who has written books on both the *V-1* and *V-2* attacks.[11] In the course of his writing, Longmate compiled the recollections of many thousands of Londoners who had lived through both attacks. His chapter comparing the two forms of attack (in *Hitler's Rockets*) is titled "Worse Than The *V-1*s." The *V-2* had the *V-1* characteristics of attacking around-the-clock, and of not having a human pilot who could be shot back at. Additionally, the *V-2* attacked without warning and could not be intercepted by defensive systems. In contrast, after a slow start, British defenses were able to down an increasing number of *V-1*s and this missile's loud pulse jet engine gave ample warning of its approach.

Additionally, the broader war situation helped to increased the psychological effects of the *V-2* compared to those of the *V-1*. The *V-1* missile attacks were in response to the D-day landing in France, which must have been an enormous psychological boost to the Allies. In contrast, the *V-2* attacks occurred when the Allied offensive in Europe had bogged down in the fall and winter of 1944-1945, and the war was dragging on much longer than had seemed likely that summer. The effects were severe. "Dedication to the Prime Minister in the solidly Labour areas which had borne the brunt of every German bombardment had never been quite as solid as the newsreels like to suggest, and public confidence in its leaders reached a new low point that winter [1944-1945]. One man then working on war damage repair in the Lambeth and Brixton areas remembers seeing 'women praying in the street for them to stop the

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10. Winston S. Churchill, *Triumph and Tragedy*, Houghton Mifflin Company, Boston, 1953 p. 39.

11. On the V-1: Norman Longmate, *The Doodlebugs*, Hutchinson & Co., Ltd, London 1981, and on the V-2: *Hitler's Rockets*, *op. cit.*

war' something he had never observed at the height of the blitz or the buzz-bombs[*V-1*]."[12] This occurred despite the fact that it was clear that, at this point in the war, England would win. If the overall war had not been going so well, one wonders at what point these psychological effects would have interfered with the war effort.

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12. *Hitler's Rockets, op. cit.*, p. 228.

SECTION IV:
THE WAR BETWEEN IRAN AND IRAQ

The war between Iran and Iraq was the first conflict in which there were exchanges of ballistic missiles between combatants. Iraq's extensive use of missiles during this conflict provides interesting background to its use of similar missiles during the Gulf War.

Missile use during the Iran-Iraq war can be divided into three phases.[1] In the initial phase only Iraq possessed missiles and it began using them about a month after it invaded Iran. First Iraq used the short-range unguided *Frog* ballistic missiles it had obtained from the Soviet Union. From October 1980 to January 1982 approximately 64 *Frogs* struck cities in the southwestern part of Iran, most often striking the city of Dezful. By May 1982, however, Iraq had been driven out of Iran. Then, five months later, in October, the Iraqis switched to using the longer-range *Scud-B* missile. From the fall of 1982 until June 1984, approximately 60 Scuds struck Iranian cities, again in the southwest part of Iran. Cities in central and eastern Iran, including Tehran, were beyond the range of these missiles. While these missiles caused many thousands of casualties, they didn't seem to have much effect on the overall war.

The second phase of the war began in March 1985. The Iraqis renewed their ballistic missile assaults on cities in southwest Iran, with the heaviest attacks to date. In the first three days they fired 25 Scuds. However, the Iranians had obtained a small number of Scuds from Libya and Syria and they were able to return fire for the first time. Furthermore, Baghdad could be targeted by Scuds from Iranian territory. Through June 1985, Iraq fired 82 Scuds. The Iranians fired only 14 Scuds in return, the low number apparently reflecting their limited supply. There was a lull until June 1986 when Iran renewed its use of missiles. Between then and November 1986 Iran fired eight Scuds--six at Baghdad and two at Iraqi oil facilities. Iraq did not respond then, but in January 1987 it fired 25 Scuds at cities in southwest Iran. This time Iran responded with 11 Scuds directed at Baghdad. After January, no more

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1. This section is drawn heavily from an unpublished chronology by W. Seth Carus and from Carus and Bermudez, *op cit.*, June 1990.

missiles were used until October 1987 when, over a 34-day period, Iran fired seven Scuds at Baghdad. Again the Iraqis did not respond. While these attacks caused numerous casualties, they still did not have much effect on the war. Most Iranian cities, including Tehran, were beyond the range of the Iraqi missile attacks. Iranian attacks on Baghdad were not very heavy--usually only one missile was fired on any given day. It is unknown whether this was to conserve missiles or whether it reflected a shortage of launchers or launch crews.

One result of these missile exchanges was that Iraq redoubled its efforts to procure a missile with a range capable of reaching Tehran. Reportedly they approached the Soviet Union for some SS-12s, but without success. Later, on August 3, 1987, Iraq announced that it had developed the *Al-Husayn* missile which it had tested to a range of 615 km. However, the Iraqis, apparently wanting to build up their stocks of *Al-Husayn*s so they could be employed on a large scale, did not use them to respond to the October-November 1987 Iranian Scud attacks. During this period Iran seems to have obtained a new and larger supply of Scuds from North Korea. In the early hours of February 29, 1988 Iran launched three Scuds against Baghdad, their heaviest attack to date. And, in response, just 15 hours later, Iraq fired its first *Al-Husayn* at Tehran. Over the next 24 hours, Iraq fired 14 *Al-Husayns* at Tehran. Given the short warning time, this was a very impressive Iraqi performance. From February 29 to April 20, 1988, Iraq launched 189 *Al-Husayns* at Iran, including 135 aimed at Tehran. The remaining 54 were targeted at five other Iranian cities, primarily Isfahan and Qom. Additionally, four Scuds were fired at Dezful. Approximately 2,000 people died from these attacks. Assuming most of these fatalities occurred in Tehran, this would mean that each missile killed roughly 13 people. Given the approximately eight times higher population density in Tehran than in World War II London, this result suggests that the *Al-Husayns* were only about one-third as effective as the *V-2* missile in causing fatalities.[2]

However, the psychological effects of the *Al Husayn* appear to have been significant. Reportedly, during this period 25 percent of the population of Tehran fled the city, while others worked in the city during the day but slept outside of it every night. Further, this appears to have been one of the series of

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2. The population density of World War II London was about 3,800 per square kilometer and that of Tehran in 1988 about 30,000 per square kilometer.

events in 1988 that finally convinced Iran to accept the end of the war. Curiously, Iraq apparently did not anticipate the impact of their new missile. Clearly the potential psychological effects were a key component of their targeting strategy, since if their only goal had been to maximize the death toll, then all of their missiles would have been targeted at Tehran, Iran's largest and most densely populated city. Instead about 30 percent of the missiles were fired at other cities, some of which--like Qom--were really too small to be attacked. But this strategy helped to increase the psychological effects by visibly demonstrating that even these cities were not safe havens. Yet, apart from this effect, the apparent Iraqi objective for the *Al-Husayn* seems only to have been to get Iran to cease the bombardment of Baghdad. And once Iraq achieved its objective, it stopped its attack.

During this same time Iran struck Iraq with more missiles than ever, firing 77 Scuds, 61 of which were aimed at Baghdad. But psychological effects similar to those suffered in Tehran did not appear to affect Baghdad. The reasons why are not obvious. Psychological effects do not lend themselves to quantitative analysis, but one can speculate as to why the results were so dissimilar. First, and perhaps most importantly, is the overall war situation which had dramatically reversed itself by the end of 1987 when Iraqi forces recaptured key territory. Second,the low level of Scud bombardment of Baghdad since 1985 may have helped the Iraqi people become inured to the missiles attacks which, in reality, did not kill that many people. In contrast, the Iraqis seem to have deliberately waited until they had enough missiles, launchers and crews to use the *Al Husayns* on a large-scale employment. Otherwise, reason suggests that they would have used them to respond to Iran's Scud attacks in the fall of 1987. Third, the Iraqi people may have been encouraged that they were giving better than they were getting, and, conversely, that the Iranians would be discouraged.

The last Scuds and *Al-Husayns* were fired on April 20, 1988 but for the Iranians the missile attacks were only the first of several events taxing their resolve to continue the war. Starting in April, after several years of being on the defensive, the Iraqis began a series of successful land offensives supported by chemical weapons which recaptured key territory. Also in April the US frigate *Samuel B. Roberts* was severely damaged by an Iranian-laid mine. This lead to various clashes between US and Iranian forces which set the stage for the accidental downing of an Iranian commercial airliner by the American cruiser *Vincennes* on July 3. Although, from a strictly logical point of view, this event had no

effect on Iranian war prospects, it was the disaster which "broke the camel's back." On July 17 Iran said that it would accept UN Resolution 598 calling for a cease-fire--a Resolution that Iraq had already accepted. After some further negotiations a cease-fire went into effect on August 20 and the eight-year war ended.

SECTION V:
THE GULF WAR

By the end of the Iran-Iraq war in 1988, Iraq had built up a sizable missile force. In the summer of 1990 there were reports that Iraq was building fixed missile launchers at the H2 (an airfield in western Iraq) in order to be able to strike against Israel.[1] In August 1990 Iraq invaded and occupied Kuwait. The United States assembled a coalition of nations, including the Arab countries of Egypt and Syria, to force Iraq out of Kuwait. For the sake of the group's unity, Israel was deliberately excluded because conventional wisdom held that several of the Arab coalition members (in particular, Syria) might drop out of the association, or even join with Iraq, if Israel were a member of the Coalition. In December Iraq announced that if it were attacked it would strike Israel.[2] This threat was particularly worrisome for two reasons. First, Iraq might use chemical weapons, including chemical weapons on ballistic missiles and, second, such a strike would be designed to draw Israel into the conflict, thereby perhaps undermining the Coalition. In preparation for the threatened action, Israel began a large-scale effort to distribute gas masks to its population and to develop other passive defensive measures against chemical attack. Israel, in fact, did stay out of the War, but the Coalition's need to halt the missile attacks against Israel enhanced the importance of the missiles far beyond their simple military effect.

On the night of January 16-17, 1991 the Coalition Forces began large-scale air attacks against Iraq. Approximately 24 hours later (the night of January 17-18) Iraq responded with ballistic missile attacks against Israel and Saudi Arabia (see the chronologies in Appendix III).[3] These and all subsequent missiles carried only conventional warheads. In all, 82 missiles, probably *Al-Husayns*, hit targets in Is-

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1. Joseph S. Bermudez, Jr. "Feedback--Iraq," *Jane's Soviet Intelligence Review,* July 1990.

2. "Tel Aviv Is 1st Target, Hussein Reportedly Says," *Los Angeles Times*, December 25, 1990, p. A1.

3. This account is based on a chronology constructed by the author using *Los Angeles Times* articles during the war and compared with a chronology published by Joseph S. Bermudez Jr. "Iraqi Missile Operations During `Desert Storm'--Update," *Jane's Soviet Intelligence Review,* May 1991 and a chronology of attacks on Israel published in the March 29, 1991 issue of *Ma'ariv*, an Israeli newspaper reproduced in the April 16, 1991 Congressional testimony of Theodore A. Postol (see Appendix II). These chronologies are basically in agreement. I am indebted to Marcy Agmon, of the Rand Corporation, for her translation of Hebrew.

rael, Saudi Arabia, Bahrain and Qatar.[4] Reportedly between 86 and 91 Iraqi missiles were launched but the others failed soon after launch.[5] Missiles launched at Israel were fired from western Iraq (in the general area of H2 and H3--airfields in western Iraq), while missiles fired at Saudi Arabia, Bahrain and Qatar were fired mostly from an area of northern Kuwait with a few launched from the vicinity of Baghdad. Due to the threat of air attack, most launches occurred at night or just after dawn, and often under conditions of heavy cloud cover.[6] In its first night of missile attacks, nine Iraqi missiles landed inside Israel and Saudi Arabia, with eight of them salvoed at Israel--this was the largest number salvoed during the Gulf War. Again, just as in the Iran-Iraq war, this demonstrated that the Iraqis were able to respond to attacks very quickly with sizable missile strikes. During the first week of the War, despite heavy Allied air attacks, the Iraqis were able to maintain a high rate of fire, including two nights (January 20-21 and January 25-26) when ten missiles struck the targeted countries. After January 26-27, the missile attacks were not as numerous but they still continued and as late as February 24-25 the Iraqis managed to hit with four missiles (two of which were salvoed). On the last night of missile attacks (February 25-26), the Iraqis still managed to strike with two missiles fired from northern Kuwait even though this was nearly 48 hours after the start of the ground war.

Thirty-nine missiles struck Israel, with most of them aimed at either Tel Aviv or Haifa, Israel's first and third largest cities, respectively. Several missiles apparently targeted the Israeli nuclear reactor at Dimona. The Iraqis announced that the *Al-Hijara* missile was used in the attacks on Dimona.[7] Several missiles landed in the West Bank [8] but apparently these were missiles aimed at either Tel Aviv or

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4. Bermudez, *ibid.*, says 81. The *Ma'ariv* chronology, *ibid.* would imply 83.

5. Bermudez, *ibid.*, says 86. Col. Bruce Garnett, the Army's *Patriot* program manager says 87. See Sean D. Naylor "Picking up the pieces," *Army Times*, May 13, 1991, p. 65. Postol says "between 86 and 91." See Theodore A. Postol "Lessons from the Gulf War PATRIOT Experience," *International Security*, Winter 1991/1992, p. 140.

6. William J. Broad, "Iraqis Using Clouds to Cover Scud Firings, Meteorologists Say," *New York Times*, January 25, 1991, p. A6.

7. Michael Kennedy, "U.S. Steps Up Combat, Launches 7 Firefights," *Los Angeles Times*, February 18, 1991, p. A6.

8. The only location on the West Bank to be specified was for a missile fired the evening of January 28 which is reported to have landed near the village of Deir Ballut. This village is just inside the West Bank, about 17 km from the outskirts of Tel Aviv. See Carey Goldberg, "It Wasn't a Scud, Palestinian Villagers Say," *Los Angeles Times*, January 30, 1991, p. A7.

Haifa which fell short of their target.[9] Neither Jerusalem, Israel's second largest city nor any smaller Israeli cities were attacked.

Forty-one missiles landed in Saudi Arabia, one struck Bahrain and one hit Qatar. The city of Riyadh and the airfield plus the surrounding populated area at Dhahran were the principal Saudi targets. The area around the small city of Hafar Al Batin as well as the airfield and military complex at King Khalid Military City in northeast Saudi Arabia were also attacked. From published accounts, it is not clear which of these two places had been the intended target, even though Hafar Al Batin is about 70 km north of King Khalid Military City. The small city of Jubail in northeast Saudi Arabia was also a target.

Up to the last day, the Iraqi missile attacks resulted in remarkably few fatalities. In Israel, only one person had been killed by the direct effects of the missile attacks and about 300 people had been injured, most of them lightly. In Saudi Arabia, only one person had been killed and less than 100 people were injured. This toll was the result of 80 missiles strikes which resulted in 18 damaging hits--nine in Tel Aviv, four in Haifa, four in Riyadh and one in Hafar Al Batin. By comparison, the World War II *V-2*s that hit London killed, on average, 4.8 persons per missile. Indeed, in the first day of the *V-2* attacks, only two missiles hit London. One did not cause any injuries but the other killed three people and injured 20 others. On the last day of the Gulf War two missiles hit in the Gulf region. One missile, aimed at Qatar, apparently did not cause any damage, but the other missile struck a US barracks in Khobar, outside of Dhahran, killing 28 people and injuring 98 others. This event in Khobar brought the total number of casualties from the 82 missiles to 30 men and women killed and fewer than 500 others injured.

The missile hit in Khobar underscores the importance of unlucky hits to the overall casualty numbers and shows that in the Gulf War, as in World War II, the distribution of damage from missile attacks is highly skewed. This can also be seen, in the opposite sense, by one of the first missiles to hit Tel Aviv. This missile scored a direct hit and caused heavy damage to an underground shelter which was empty but ironically one which 60 people had planned to use, but at the last minute they had sought out

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9. A similar result occurred during the *V-2* attacks on London when many missiles fell short and landed in the county of Essex.

another shelter.[10] If they had been in the shelter, most of them--if not all of them--would have died.

The number of fatalities caused by the Gulf War missile attacks seems to be about one-fifth to one-third of the number of deaths one might expect based on the characteristics of the *Al-Husayn* missile and the size and population of the targeted cities. What might account for this difference? The most obvious difference is that the Gulf War was the first one in which missile defenses were used. This subject, which has become very contentious, will be discussed in more detail below but, as we will show, the effectiveness of the Iraqi missile attacks on cities was so variable that no definitive conclusions about the *Patriot*'s performance can be drawn from the casualties or damage caused by the *Al-Husayn* attacks.

The effectiveness of an *Al-Husayn* attack depends on the lethality of the missile, its CEP and the size and population of the target cities. As previously noted, during the Iran-Iraq war the *Al-Husayn* seems to have been about one third as effective as the *V-2* missile in causing fatalities. On impact the *V-2* weighed about 4 tonnes and contained about 750 kg of explosive while the *Al-Husayn* weighed about 2 tonnes and is estimated to contain 135-300 kg of explosive,[11] so the difference in effectiveness is not surprising. The population density of Tel Aviv is about three times that of World War II London so that the number of people killed per missile should be about the same as the *V-2*--around five.[12] The population density of the built-up area of Haifa is about one-half that of Tel Aviv, and the population density of Riyadh a little less than one-fifth that of Tel Aviv leading to an expected 2.5 persons and one person killed per missile, respectively.[13] Combining this information with the number of damaging hits per city would

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10. This was a missile which hit the morning of January 19, 1991. See Carey Goldberg, "Tel Aviv Left Fatigued but Still Feeling Lucky," *Los Angeles Times*, January 20, 1991, p. A5.

11. The weights of the missile bodies are important since for these missiles their kinetic energy is comparable to the explosive energy contained in the warhead. For example a 1,000 kg mass traveling at Mach 5 has the kinetic energy equal to the explosive energy of 350 kg of TNT. A German test of a *V-2* without a warhead produced a crater 45 feet deep and 120 feet across. See W. C. Yengst, J. B. Swenson, and K. H. Mueller, *Evaluations of Collateral Damage - Final Report*, Science Applications, Inc., La Jolla, CA, 15 November 1976, pp. 89-97 and Ernst Klee and Otto Merk, *The Birth Of The Missile--The Secrets of Peenemunde*, E. P. Dutton & Co., Inc., New York, 1965, p. 54.

12. We estimate the population density of World War II London to have been about 3,800 per square kilometer. In 1983 the population density of the Tel Aviv district was 5,900 per square kilometer. The actual urban area of Tel Aviv appears to be about one half of this area, leading to an estimated population density of 11,800 per square kilometer. See *Atlas Of Israel*, Third Edition, Macmillan Publishing Company, New York, 1985, sheet 23.

13. In 1983 the population density of the Haifa sub-district was 1,450 per square kilometer. Since the actual urban area of Haifa is much smaller than the area of the Haifa, sub-district we increased the population density by about a factor of four to 5,900 per square kilometer. See *Ibid.* In 1990 the population of Riyadh was about 1,650,000 and the built-up area of Riyadh was 770 square kilometers leading to a population density of 2,150 per square kilometer. See *Riyadh A to Z*, produced and published by Eng.

lead to 61 expected fatalities versus the thirty that actually occurred (see Table 1)[14]. But since as we have shown the number of fatalities per damaging missile hit is highly skewed, it is hard to assess the significance of the difference between the number of expected and actual fatalities.

A method of analysis which avoids this problem is to consider only whether a particular missile caused damage or not. As we will discuss below, the most likely CEP for the *Al-Husayn* missile is about 2 km. Therefore, a properly functioning *Al-Husayn* would have about a 97 percent chance of striking Tel Aviv or the central core of Riyadh. Even assuming that one-third of the missiles that landed in the vicinity of these two cities had gross errors which caused them to miss their aim points by large margins, there should have been, in the absence of *Patriots*, 19 expected hits in Tel Aviv instead of the nine that actually occurred, and 14 expected hits in Riyadh rather then the four that actually occurred.[15] This deficiency in damaging hits is statistically quite significant--the chance of this occurring randomly at either city is less than 1 in 10,000. The solution to this apparent inconsistency might be to assume that the CEP of the *Al-Husayn* is much larger than 2 km or that the fraction of *Al-Husayn*'s with gross errors is larger than one-third. The problem with this solution is that then the results at Haifa and Hafar Al Batin become highly improbable and it is especially hard to see how any realistic CEP and gross error percentage for the *Al-Husayn* could produce the results that actually occurred at Riyadh.[16] Indeed, given that Tel Aviv is at least twice the size of Haifa, it is hard to reconcile by statistical variation alone the fact that only nine out of 30 missiles caused damaging hits in Tel Aviv while four out of six missiles caused damaging hits in Haifa.

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Zaki M. A. Farsi, Farsi Maps, Jeddah, Saudi Arabia, First Edition, June 1990, p. 26.

14. We have assumed the population densities of Dhahran and Hafar Al Batin to be the same as Riyadh. Since only a small fraction of the total actual or expected hits occurred in these two cities, our results are not sensitive to this assumption. The term "expected" is used here in the statistical sense.

15. If anything, an estimate of one-third for the fraction of missiles having gross errors is probably high; one-fourth to one-fifth is probably closer to the truth. Riyadh is so large that we assumed that one-half of the missiles with gross errors still hit within Riyadh's built-up area whereas for all of the other targets, we assumed that all of the missiles with gross errors missed.

16. Riyadh experienced explosive growth in the 1980s. Its core is about 65 square kilometers which is about the same size as the principal section of Tel Aviv's urban area. But the entire city is 1,600 square kilometers which is almost the size of the London Civil Defense Region in World War II. Of this 1,600 square kilometers, only 770 square kilometers is built up but this is still about nine times larger than all of Tel Aviv's urban area. Most of the growth in Riyadh is to the north of its central core which is exactly where missiles with gross errors would tend to land (i.e., short of the target). See *Riyadh A To Z, op. cit.*.

TABLE 1

ACTUAL VERSUS EXPECTED EFFECTIVENESS OF *AL-HUSAYN* MISSILE ATTACKS DURING THE GULF WAR

City	Actual No. of Missiles Impacting in Vicinity	Actual No. of Damaging Impacts	Actual No. of Fatalities	Expected No. of Fatalities*	Expected No. of Damaging Impacts**	Expected No. of Fatalities***
Tel Aviv	30	9	1	45	19	95
Haifa	6	4	0	10	2	5
Dimona	3	0	0	0	0	0
Riyadh	17	4	1	4	14	13
Dhahran	16	1	28	1	3	3
K.K.M.C.-H.A.B.+	7	1	0	1	1	1
Al-Jubayl	1	0	0	0	0	0
Bahrain	1	0	0	0	0	0
Qatar	1	0	0	0	0	0
	82	19	30	61	39	117

* Based on the actual number of damaging hits, the *Al-Husayn's* effectiveness during the Iran-Iraq War, and the population density of the target city

** Based on assumed 1/3 of *Al-Husayns* with large gross aiming errors, *Al-Husayns* with 2 km CEP, the actual area of the target city, and assuming no *Patriot* defense

*** Based on the expected number of damaging hits, the *Al-Husayn's* effectiveness during the Iran-Iraq War, and the population density of the target city

\+ King Khalid Military City–Hafar Al Batin

One possible cause of the nonstatistical variation in damaging hits among the different cities is the *Patriot* anti-missile system. The Gulf War was the first time that such a system was used to counter ballistic missile attacks. Both proponents and opponents of the Strategic Defense Initiative (SDI) consider the *Patriot's* performance in the Gulf as a test of the desirability of various SDIO programs even though there are significant differences between the *Patriot* and the other systems. In the discussions here, the focus is on the *Patriot's* performance strictly in terms of how well it intercepted *Al-Husayns* during the Gulf War.

The *Patriot* was originally designed as an air defense system. Subsequently it was upgraded twice to provide capability against short-range ballistic missiles.[17] The first modification, PAC-1, changed the system's software to enable the system to track and intercept ballistic missiles in addition to aircraft. The second, PAC-2, modified the warhead to make it more lethal to ballistic missiles. Originally this improved warhead was not scheduled to be available until 1991, but following the invasion of Kuwait, production was sped up and it became available in the fall of 1990. "Live-fire" tests of *Patriot* batteries were conducted in the United States in September 1990, and the batteries were deployed and operational in Saudi Arabia one month later. Before the January outbreak of war, three additional software changes were made to improve the systems' capability against *Al-Husayns*.[18] In December, Iraq test fired *Al-Husayns* on its on territory. These tests revealed flaws in the procedure whereby DSP (Defense Support Program) infrared early warning satellites were able to alert the *Patriots* of Iraqi missile launches.[19] All of these events helped to ensure that the *Patriots* in Saudi Arabia were well prepared when the War began. In contrast, although Israel had obtained two *Patriot* batteries before the war, its crews were still training in the United States and, initially, Israel refused to use American crews. Once the war began, however, the Israeli crews returned home and American crews and additional *Patriot* batteries were brought in from Europe. The first *Patriot* intercepts were made less than 12 hours after their crews ar-

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17. Simon Elliott, "Technology on Trial," *Flight International*, February 13-19, 1991, p. 32.

18. Statement of Col. Bruce Garnett as reported by Sean D. Naylor, *op. cit.*

19. Robert C. Toth, "Iraqi Missile Test Caught U.S. Completely Off Guard," *Los Angeles Times*, December 21, 1990, p. A1.

rived in Israel.[20] Therefore one might expect that the better *Patriot* performance would have been in Saudi Arabia, but as we will see the differences in the *Patriot's* effectiveness in the two countries is not that clearly defined.

In operation the *Patriots* were alerted to a missile launch by the DSP satellites.[21] If the missile were headed toward the battery it would be detected by radar about six to seven minutes later at a range of over 100 km. By design, two *Patriots* would be launched at the incoming missile and the kill would occur 15 to 18 seconds later at a range of 10 to 30 km.[22] If there were more than one incoming missile, the various batteries would exchange information so that each incoming missile would be engaged and that only one battery would fire at any one missile.

Factually, what can be said about the *Patriot's* performance? Certainly the *Patriot* demonstrated a remarkable ability to intercept the *Al-Husayn* missile. It is reported to have intercepted 45 of 47 missiles engaged.[23] It has not been reported what percentage of engagable missiles the system actually encountered or destroyed, but clearly it is also quite high. This high an intercept capability certainly was not anticipated before the war began. On the other hand, once an intercept is made, the *Patriot* obviously has a limited ability to destroy the incoming missile. In Tel Aviv, Riyadh and Dhahran large sections of missiles, including whole fuel tanks, fell to the ground after interception. In the televised camera footage, often after intercept,[24] pieces of flaming debris could be seen falling to the ground causing damaging impacts. There was a report of at least one unexploded warhead landing after intercept[25] and the most damaging impact in Riyadh occurred after a *Patriot* intercept when a part of a missile (probably an intact

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20. Robert Skelly, "Critics Fire Misinformation at Patriot," *Defense News*, May 13, 1991, p. 33. Robert Skelly is vice president for public and financial relations for the Raytheon Co., which manufactures the *Patriot* missile.

21. This was confirmed by Henry Cooper, Director of the U.S. Strategic Defense Initiative Organization. See Vincent Kiernan, "Cooper Lifts Veil of Secrecy To Applaud DSP," *Space News*, April 1-7, 1991.

22. "U.S. Army Patriot Proven in New Role As Anti-Tactical Ballistic Missile Weapon," *Aviation Week & Space Technology*, February 18, 1991, p. 49.

23. Mark Hewish, "War-winning technologies: Patriot Shows its Mettle," *International Defense Review*, May 1991, p. 457.

24. Such was the nature of this war that the author saw somewhere between 5 and 10 *Patriot* intercepts on television during the war.

25. Jeffrey M. Lenorovitz, "Poor Workmanship Discovered In Scud Missile Fragments," *Aviation Week & Space Technology*, March 11, 1991, p. 61.

front section, including the warhead) hit and demolished part of a government building.[26] Clearly there is a need for substantial improvement in the *Patriot's* lethality. Ultimately it is likely that a hit-to-kill system will be needed to replace the current *Patriot*'s proximity-fused warhead.

In April 1991 Theodore Postol, a professor at the Massachusetts Institute of Technology, in widely-reported testimony before Congress, suggested that in Israel the *Patriots* were actually counter-productive, causing more damage and injuries than they prevented. However, Postol's analysis contains important arithmetic errors and ignores the fact that the small sample size and highly skewed distribution of the missile damage makes his analysis statistically insignificant. In a more recent article Postol has admitted as much but continues to make methodological and arithmetical errors which leads him to conclude that the data at least suggests that the *Patriot* was counterproductive. But when such errors are removed there is nothing to suggest that the *Patriot* actually made matters worse. (Postol's analysis is examined in more detail in Appendix II).

Having shown that the *Patriot* did not make matters worse, there is still the question of whether the *Patriot* made things better and, in particular, whether *Patriot* significantly reduced the number of damaging hits suffered by the various cities it was defending. Certainly the fact that the number of damaging hits is significantly less than expected supports the idea that the *Patriot* was effective in reducing the number of damaging hits. Showing this definitively, however, is difficult due to the fact that there appears to be other significant sources of variability in the number of damaging hits achieved by the *Al-Husayn* attacks. As was pointed out earlier, the fact that four out of six missiles caused damaging hits in Haifa, while only nine out of 30 missiles caused damaging hits in Tel Aviv is hard to explain by statistical variation alone. Nor does it seem that the *Patriot* is the likely cause since both cities appear to have been defended by the *Patriot* system for the same length of time. Furthermore, looking at the eleven missiles that landed in Tel Aviv before the *Patriot*s began operation, only four damaging hits (36 percent) occurred--a result which is, again, statistically improbable given the size of Tel Aviv and our assumed characteristics of the *Al-Husayn*. Of the nineteen missiles to hit in the Tel Aviv area during the time of the

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26. This was a missile which hit on the evening of January 25th. See Daniel Williams and J. Michael Kennedy, "Patriots Shoot Down 6 of 7 Scuds Over Israel," *Los Angeles Times*, January 26, 1991, p. A1.

Patriots' operation, only five (26 percent) resulted in damaging hits. But this reduction is not statistically significant. Clearly there are other factors which caused the number of damaging hits to be significantly less than would otherwise be expected and which caused the effectiveness of the *Al-Husayn* to vary substantially from city to city.

The clearest indication that the *Patriot* reduced the number of damaging impacts is at Riyadh where there were only four damaging hits from 17 missiles. As was pointed out above, given the size of Riyadh, it is hard to explain the poor performance of the *Al-Husayn* using operational factors alone. But given the evidence that there are other factors which caused the *Al-Husayn's* erratic performance, it is difficult to quantify *Patriot*'s effectiveness.

One can only speculate as to the factors causing such variability in the performance of the *Al-Husayn*--they could range from differences in separate production batches of the *Al-Husayn* (which might affect CEP or reliability) to the use of non-optimal target coordinates for some of the cities being attacked. Though the data suggests that the *Patriot* significantly reduced the number of damaging hits, this variation in missile effectiveness caused by an unknown factor or factors makes it impossible to demonstrate this definitively. However, this is not to say that the *Patriot* did not have a substantial effect in reducing the number of damaging hits, only that with so much other variability in the effectiveness of the *Al-Husayn*, the *Patriot's* effectiveness cannot be demonstrated statistically.

One can attempt to determine the *Patriot*'s effectiveness more directly in terms of the percentage of times that it struck the incoming *Al-Husayn* missiles and, in particular, how often it destroyed the missile's warhead. In the spring of 1991, it was reported that in intercepts over Saudi Arabia, the *Patriot* destroyed the warhead of the incoming missile 90 percent of the time, and in intercepts over Israel, 50 percent of the time.[27] This fact, regardless of statistical evidence, would have strongly indicated that the *Patriot* significantly reduced damage levels. Recently, however, Reuven Pedatzur of the Jaffee Center in Tel Aviv and Theodore Postol have challenged this assessment on the basis of an unpublished Israeli

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27. Robert Skelly, *op. cit.*

analysis.[28] They have stated that the Israelis observed 12 of the 17 *Patriot* intercepts over their country using infrared cameras, and that in all 12 cases the incoming missile warhead was not destroyed. From this and other data, the Israelis concluded that none of the 17 missile warheads were destroyed by *Patriot* missiles. Since there were no recording devices on the *Patriots* in Saudi Arabia, they claim that for the 30 intercepts in that country there is no way to determine the rate of destruction, but they imply that it might have been as low as in Israel.

Contrary to their assertions, however, it is possible, even without recording devices, to tell if a warhead was destroyed or impaired by the damage it causes on the ground, and this apparently is the basis of the US Army's higher estimates of the *Patriot's* effectiveness. The Army recently, however, issued a statement lowering its estimate to 70 percent of the *Al-Husayn* warheads destroyed over Saudi Arabia, and only 40 percent of the warheads destroyed over Israel. To further complicate matters, Steven Hildreth, a defense specialist at the Congressional Research Service has said that he found Pedatzur and Postol's case to be "worthless," but at the same time said that on the basis of data provided to him by the Army he could only confirm that *Patriot* had destroyed one warhead over Israel.[29] Therefore, the question of the *Patriot's* effectiveness in destroying missile warheads must still be considered an open one. The resolution of this issue is essential to determining the overall effectiveness of the *Patriot* system.

One area where the *Patriot* system was of undeniable benefit was in reducing the psychological effects of the missile attacks. As previously stated, the psychological effects of the earlier *V-2* missiles were magnified by the lack of any defense against them. The *Patriot*, even if not perfect, provided a visible means of countering incoming missiles and even the critics of the *Patriot* acknowledge this.[30] Since the psychological effects of the attacks and the need to negate them in order to keep Israel out of the war were central to the conflict, the *Patriot* missile clearly played an important role in the Gulf conflict. If,

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28. Reuven Pedatzur and Theodore Postol, "The Patriot Is No Success Story," *Defense News*, December 2, 1991, p. 24.

29. David F. Bond, "Army Scales Back Assessments Of Patriot's Success in Gulf War," *Aviation Week & Space Technology*, April 13, 1992, p. 64.

30. For example, Israeli Defense Minister Moshe Arens. See "Arens Says War Proves Need For Targeting Mobile Missiles," *Aviation Week & Space Technology*, June 24, 1991, p. 26. Israeli criticism of the *Patriot* seems to be motivated by their desire to protect their *Arrow* anti-missile program.

however, it is found that the *Patriot* actually had a low effectiveness against the *Al-Husayn*s then this psychological benefit might not occur in future conflicts.

Other than the attacks on urban areas, the direct effects of the missile strikes were not significant. There were reports that, on several occasions, an airfield in Saudi Arabia (presumably Dhahran) was hit by debris from intercepted missiles and that one time several F-15s were slightly damaged.[31] The only target attacked that might be considered a point target was the Israeli plutonium production reactor at Dimona. The Israelis have not published details of this reactor so, for the purpose of this study, a similar reactor in India (the CIRUS) has been used for computing the probability of achieving a missile hit. The entire reactor complex of CIRUS, including support buildings, covers only about 0.0025 square km.[32] Even with a CEP of 1 km, a single missile would have only a 0.06 percent chance of hitting the reactor complex. The Iraqis apparently fired only three missiles at the reactor, which would mean the chance that any of these missiles scored a hit would only be 0.17 percent. Thus it is not surprising that there does not seem to have been any damage at the Dimona reactor from these attacks.

The indirect effects of the missile attacks were quite significant--partly due to the need to constrain Israel from joining the war and, partly, due to the fear of chemical attacks. Numerous Coalition air sorties were flown specifically searching for mobile missile launchers. During the first week of the air campaign, it was stated that the equivalent of an entire day's worth of sorties had been spent looking for mobile missiles.[33] This enormous diversion of air resources, which was not very successful, was made even more striking by the fact that Iraq's air force, consisting of hundreds of modern aircraft including *Mirage* F-1s, MiG-29s and Su-24s, managed to fly only a few sorties and wound up fleeing to Iran. Apparently very few mobile missiles or their launchers were destroyed through the Coalition's efforts.[34]

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31. Julie Bird "Early Gulf Attacks by Scuds Cause Slight F-15C Damage," *Defense News*, March 4, 1991, p. 23.

32. R. D. Sage, D. D. Stewart, N. B. Prasad and H. N. Sethna, "The Canada-India Reactor," *Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy*, Vol. 10, Research Reactors, United Nations, Geneva 1958.

33. "Allies Shift Air Attacks To Break Ground Units," *Aviation Week & Space Technology*, January 28, 1991, p. 20.

34. Moshe Arens, then-Israeli Defense Minister, went so far as to state, "To the best of my knowledge, not a single mobile missile was found and destroyed from the air." See "Arens Says War Proves Need For Targeting Mobile Missiles," *op. cit.*

Even the effectiveness of the air attacks against the fixed launch sites seemingly was not that great. Despite official Coalition pronouncements that all of these sites had been destroyed early in the war, Iraq, in a declaration to the United Nations, has stated that 28 (roughly half the prewar number) of the fixed sites in western Iraq were still operational.[35] Second only to bad weather, the ballistic missiles were an important factor impeding the air campaign against Iraq.

Several observations can be made about Iraq's ballistic missiles. The first concerns their CEP. Before the Gulf War, public estimates of their CEPs were as low as 0.3-0.5 km and as high as 3-4 km. Based on their performance in the war and the way in which the Iraqis employed them, now it is possible to narrow this range. Clearly the missiles did not have CEPs as low as 0.3-0.5 km. The Iraqis did not attack Jerusalem, although it is Israel's second largest city. Apparently they did not wish to risk damaging the Dome of the Rock (Islam's third holiest site) and/or the largely Arab population in eastern Jerusalem. But with a CEP of only 0.5 km, it should have been possible to strike only the Israeli western part of the city. The psychological benefits to the Iraqis would have been considerable since even a few attacks on Jerusalem would have put a significant additional part of the Israeli population at risk and denied the population an important safe haven. Similarly, with a 1 km or even perhaps with a 1.5 km CEP the smaller but still significant Israeli cities of Beersheba and Natanya could have been attacked with reasonable chances of success. On the other hand, if the CEPs had been as great as 3-4 km, a city as small and irregularly shaped as Haifa would have had a low probability of being hit whereas of the six missiles aimed at it, four seem to have struck close enough to have caused significant damage. With a CEP as large as 4 km, even Tel Aviv would be hard to hit reliably. Given these observations and the general performance of the missiles during the War, a reasonable estimate of the Iraqi missile CEP (most likely the *Al-Husayn*) is approximately 2 km with an uncertainty of plus or minus of about 0.5 km.

An additional observation can be made based on the distances that the Iraqi missiles traveled (see Table 2). The Iraqis appeared to have fired their missiles from three locations. General Norman Schwarzkopf, then-US Central Command Commander-in-Chief and overall commander of Operation

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35. Melissa Healy and James Gerstenzang "Iraq Says It Has 11,131 Chemical Warheads in Stock," *Los Angeles Times*, April 20, 1991, p. A1.

TABLE 2

MISSILE FLIGHT DISTANCES

LAUNCH POINT	TARGET	DISTANCE (km)
	ACTUAL ATTACKS	
NKFP*	Hafar Al Batin	240
NKFP	King Khalid Military City	310
NKFP	Jubail	370
NKFP	Dhahran	480
NKFP	Bahrain	510
NKFP	Riyadh	600
H-2	Haifa	530
H-2	Tel Aviv	560
H-2	Dimona	580
Baghdad	Hafar Al Batin	570
Baghdad	King Khalid Military City	610
	HYPOTHETICAL ATTACKS	
Baghdad	Jubail	850
Baghdad	Haifa	880
Baghdad	Tel Aviv	910
Baghdad	Dhahran	970

*North Kuwait Firing Point

Desert Storm, indicated that the missiles fired deep into the Saudi theater were all launched from an area in northern Kuwait.[36] We refer to this area as the North Kuwait Firing Point (NKFP).[37] The missiles fired at Israel were all launched from western Iraq. For purposes here, we have designated the airfield at H-2 as a nominal location. Generally, missiles from both of these locations were fired at night or early morning and often under cloud cover, presumably due to the threat of counter-attack posed by Coalition aircraft. Due to the heavy air defenses surrounding Baghdad, the Coalition aircraft could only attack the city at night using F-117s. Iraq took advantage of this fact by firing a few missiles during the daytime from Baghdad into northern Saudi Arabia. The target of these attacks generally has been reported as King Khalid Military City (KKMC), but wartime accounts of at least one of these attacks described damage to the town of Hafr Al Batin.[38] These cities are 70 km apart and it is unlikely that a missile fired at KKMC would fortuitously hit Hafr Al Batin. Table 2 lists the distances from these firing points and the various targets in each theater. Distances to Hafr Al Batin and King Khalid Military City from both the NKFP as well as Baghdad are given, although it is not certain that missiles from the NKFP were launched at these two targets.

The results of these attacks lead to interesting conclusions regarding Iraq's missile capabilities. From the NKFP, only the town of Hafr Al Batin is within range of an unmodified Scud missile. On the other hand, all of the other cities are 610 km or less away--in other words, within the range of the *Al-Husayn*. If Iraq possessed a missile with a 850-900 km range (the nominal range of the *Al-Abbas*) then it should have been possible to attack Jubail, Haifa and, perhaps, even Tel Aviv by launching missiles from Baghdad during daylight hours. Firing even a few missiles during daylight--the only time Israeli and Saudi civilians perceived as safe--would have been psychologically very damaging. There are some reports that the *Al-Abbas* has a range of only 700-800 km. However, even this range would have permitted

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36. February 27, 1991 military briefing in Riyadh, Saudi Arabia.

37. For these calculations, the position used was: thirty degrees, zero minutes north; forty seven degrees, forty minutes east. In all likelihood the missiles were actually fired from a number of different locations near this point.

38. Melissa Healy and J. Michael Kennedy, "Higher Iraqi Tank Losses Reported; 4th Carrier in Gulf," *Los Angeles Times*, February 15, 1991, p. A6.

Riyadh to be attacked from locations in southern Iraq rather then having to use a site in northern Kuwait. All these observations strongly suggest that virtually all--if not all--of the Iraqi missiles used in the Gulf War were *Al-Husayns*, and that Iraq could not use or does not possess missiles with ranges significantly longer than that of the *Al-Husayn*. What could explain this? Some reports claim that the *Al-Abbas* did not achieve its anticipated range while other reports cite its range as low as 700 km.[39] If this were true, then with such a small difference, its use would be hard to differentiate from that of the *Al-Husayn*. It is also possible that if the range difference between the two missiles were that small, then the Iraqis did not deploy the *Al-Abbas* after they tested it in 1988. Another possible explanation, put forth in a German report, is that the *Al-Abbas* achieved its increase in range (over the *Al-Husayn*) by the use of higher energy, cryogenic fuel.[40] This could mean that the Iraqis replaced the nitric acid oxidizer with liquid oxygen. With the UDMH fuel, this would lead to about a 13 percent increase in specific impulse and an increase in range.[41] However, while nitric acid oxidizer is storable, liquid oxygen is not. Possibly because of this fact, the Iraqis did not finish developing the *Al-Abbas*. But even if the *Al-Abbas* had been fully developed and deployed, this fact would have made it operationally impossible to make liquid oxygen available for the missiles. After the war Iraq did not declare the existence of any *Al-Abbases* to the United Nations, but given Iraq's false declarations concerning its nuclear program, this, in and of itself, does not mean much.

As a result of the Gulf War, one can draw several intelligence-related conclusions. First, our knowledge about the *Al-Husayn* missile should be greatly increased. Since an unexploded warhead landed in Riyadh, now the warhead size should be known. An analysis of the exact impact points of the missiles, even though the precise aim point is not known, should yield a good estimate of the CEP (we have already made an approximate estimate above). If an *Al-Husayn* was actually captured (although

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39. For example, see John D. Morrocco, "Pentagon Defends Ground Buildup in Gulf, Says Airpower Alone Cannot Achieve Goal," *Aviation Week & Space Technology,* December 10, 1990, p. 80.

40. "We Have Power in the Tank," *Der Spiegel,* February 25, 1991, pp. 112-115, reproduced in *JPRS Report: Nuclear Developments,* JPRS-TND-91-005, March 28, 1991, p. 34.

41. UDMH is unsymmetrical dimethylhydrazine. Specific Impulse is a measure of the energy available from propellants and is defined as the thrust obtained from a given mass of propellant consumed in one second. See Samuel Glasstone, *Sourcebook On The Space Sciences,* D. Van Nostrand Company, Inc., Princeton, New Jersey, 1965, Chapter 3.

there is no report of this), then even more information eventually may be available. With regard to the numbers of *Al-Husayn* mobile launchers, General Schwarzkopf complained that the prewar estimates were low, perhaps by a factor of ten.[42] As documented noted above, the Coalition's intelligence on the fixed launch sites was also quite poor (although, in this case, it is unclear whether the problem was with prewar intelligence or with our ability to perform damage assessment). The recent discovery of an Iraqi uranium enrichment program based on calutrons further indicates serious limitations in the West's intelligence efforts focused on Iraq's special weapons programs. However, it is uncertain whether the problem is with the intelligence agencies themselves or with the high-level direction they receive. It seems obvious that most of our pre-war intelligence resources were devoted to tracking the Soviet Union and what little intelligence effort spent on the Gulf was probably focused on Iran. The proliferation of long-range missiles (both ballistic and cruise) and the development of more lethal warheads in a number of countries clearly indicates that more intelligence efforts need to be directed at those countries in order to aid the US efforts to block their development, and also to insure that in the event of conflict there will be much better information about the nature of the threat.

There are still unanswered questions about Iraq's use of missiles in the Gulf War. By far the most important is why Iraq did not place chemical warheads on its ballistic missiles? During the war speculation was that Iraq might not have chemical warheads, but in a postwar declaration to the United Nations, Iraq declared that it had 30 chemical warheads.[43] Therefore, possible explanations range from the fear of retaliation, to a belief that the warheads would be ineffective given the anti-chemical measures taken in Israel and Saudi Arabia, and to possible operational factors that might have prevented their use. Of lesser concern, but still interesting, is the question of why missile attacks were not launched against Incirlik Air Field in southeast Turkey. US aircraft operating from this airfield repeatedly attacked targets in northern Iraq. The airfield was defended by *Patriot* batteries, but just the fact of an attack (which Iraq could have justified as self-defense) might have energized Turkish opposition to Turkish Prime Minister Ozal's firm decision to support the coalition against Iraq. However, questions like these

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42. February 27, 1991 military briefing in Riyadh, Saudi Arabia.

43. John J. Goldman, "Iraq Tells of Chemical Arms Cache," *Los Angeles Times*, April 19, 1991 p. A1.

are likely to remain unanswered unless there is a high-level defector from Iraq or other reliable sources of information emerge.

SECTION VI:
TRENDS IN THE WORLDWIDE MISSILE THREAT

There are several trends in the Third World missile threat that will likely lead to a further exacerbation of Third World missile capabilities. Four areas of particular interest are: 1) the growth of autonomous missile programs; 2) the continued increase in missile range beyond the 300 km of the Soviet-supplied Scud missiles; 3) a significant improvement in missile CEP which is now typically in the 1-2 km range; and 4) the possibility of using more lethal warheads than just simple unitary high-explosive warheads, including nuclear, chemical, and improved high explosive warheads.

THIRD WORLD AUTONOMOUS MISSILE PROGRAMS

The Soviet Union, either directly or indirectly, supplied *Scud B* missiles to eight Third World countries (Afghanistan, Egypt, Iran, Iraq, Libya, North Korea, Syria, and Yemen).[1] Five of these eight countries have launched them against opponents; most notably, Afghanistan has fired over 2,000 since 1989.[2] Simply importing the missiles, however, has certain drawbacks. As Iran learned during its war with Iraq, there is substantial uncertainty over when future shipments of missiles might arrive and, consequently, a need to husband missiles to ensure that a supply is maintained. A more important drawback is that reliance on only importing missiles forestalls the opportunity for foreign technology to be incorporated into internal missile production programs in order to produce more capable missiles.

However, nine Third World countries have their own autonomous missile programs, as listed in Table 3. These programs are termed "autonomous" rather than "indigenous," since indigenous would imply that these countries are using only indigenous technology, whereas actually all of these countries

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1. Martin Navias, "Ballistic Missile Proliferation in the Third World," *Adelphi Papers*, #252, The International Institute for Strategic Studies, London, Summer 1990, p. 30.

2. Joseph S. Bermundez Jr., "Ballistic Missiles in the Third World--Afghanistan 1979-1992," *Jane's Intelligence Review*, February 1992, p. 51.

TABLE 3

AUTONOMOUS THIRD WORLD MISSILE PROGRAMS

(Range greater than 200 km)

COUNTRY	MISSILE	RANGE (KM)	STATUS
CHINA			
	CSS-1	1200	50 deployed since 1970
	CSS-2	3000	15-20 deployed since 1971
	CSS-3	7000	10 deployed since 1978
	CSS-4	10000	10 deployed since 1980
	M-9	600	Being developed for export
INDIA			
	Prithvi	250	First tested in 1988; production for Indian Army to begin in 1992
	Agni	2500	Tested in 1989
	PSLV-derived	At least 5000	Large 1st-stage ground-tested in 1989
PAKISTAN			
	Hatf 2	300	Tested in 1989
IRAQ			
	Al-Husayn	600	Tested in 1987. Large numbers employed in 1988 and 1991
	Al-Abbas	700-900	Tested in 1988
	Tammuz-1	2000	First stage tested in 1989
ISRAEL			
	Jericho 1	500	Deployed in 1973
	Jericho 2	800-1500	Tested in 1987
	Shavit-derived	At least 5000	Shavit launched in 1988
SOUTH AFRICA			
	Jericho 2-derived	1500	First tested in 1989
NORTH KOREA			
	Scud PIP	500	First tested in 1990
	No-Dong I	Greater than 1000	Under development
BRAZIL			
	Sonda IV-derived	1000	Sonda IV first tested in 1984
	VLS-derived	At least 5000	VLS to be first tested in 1994
ARGENTINA			
	Condor II	1000	Development continuing

have relied heavily on imported technology. For example, Israel received its initial missile technology from France and appears to have passed it on to South Africa. Iraq and North Korea relied heavily on Soviet *Scud-B* missile technology. These programs are autonomous even though initially they had to import technology, because they can now utilize it in their missile programs without foreign assistance. They can now produce missiles on their own and, perhaps most importantly, export them to other countries. North Korea, for example, has supplied Scud PIPs to Syria and Iran.[3] It is striking to note that of these nine countries, only two (China and Israel) had test fired a missile before 1984. This explosive growth in autonomous missiles programs in less than a decade is one reason why the issue of missile proliferation has become so important.

Even with these autonomous programs, there is still a need for the MTCR to control exports to these countries. These countries, by and large, are still heavily dependent on foreign technology to upgrade their ongoing missile programs. In fact, it is only because of their current missile efforts that they can utilize the imported technology.

INCREASING MISSILE RANGE

Of the nine autonomous missile programs listed in Table 3, eight involve the development of missiles with a range greater than the 300 km of the Soviet-supplied *Scud-B*. In addition, in 1988, China supplied Saudi Arabia with modified *CSS-2s* with a range of 2800 km and, as previously mentioned, in 1991, North Korea supplied Syria and Iran with a 500 km range *Scud PIP*. Most of these missiles have a range of 2500 km or less, although China has already developed ICBMs, and the space launch vehicle programs of three others (Israel, India, and Brazil) hold the promise of producing missiles with a range of at least 5000 km. Therefore, in the short run, these efforts to produce longer-range missiles will have implications mainly for theater use. Longer-range missiles could be used to draw more countries into conflict with each other; for example, Iraq was able to attack Israel with its 600-650 km *Al-Husayn* mis-

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3. Produced in North Korea, the *Scud-PIP* is an improved version of the *Scud-B*. Joseph S. Bermudez Jr., "Syria's Acquisition of North Korean 'Scuds'," *Jane's Intelligence Review*, June 1991. Joseph S. Bermudez, Jr., "Ballistic Missiles in the Third World---Iran's Medium-Range Missiles," *Jane's Intelligence Review*, April 1992.

sile, something it was unable previously to do with a 300 km *Scud-B*. Longer ranges will permit deeper strikes into countries that border one another, as with Iraq's attacks on Tehran during the Iran-Iraq war. Or they can be used to provide a greater standoff from targets, permitting mobile missiles a larger area within which to hide. Europe, especially the south and the east, could be threatened by such missiles launched from North Africa or the Mideast. Indeed, in 1986, Libya fired two 300 km range *Scud-Bs* at a small Italian island in the Mediterranean Sea in response to US air strikes.[4] From Libya, Rome is only 1000 km away and London is only 2300 km away. Both Italy and Greece are purchasing *Patriot* missiles with the PAC 2 upgrade which enables the *Patriot* to intercept ballistic missiles. However, the increased velocity of longer-range missiles will make it difficult for the *Patriot* to intercept them.

The increase in missile range will alter the threat in other ways as well. A longer range missile is larger and weighs more than a shorter-range missile. These differences increase production costs which, in turn, will probably lead to a lower number of missiles being manufactured. Missile size and weight depend on the level of technology but, typically, a 300-600 km range missile will weigh about 6-7 te, a 2000-3000 km range missile will weigh about 15-25 te, and a 7,000-10,000 km range ICBM will weigh 50-100 te or more. By comparison, a main battle tank weighs about 50 te. Increases in size and weight also make it harder for missiles to be mobile and, as a result, many may have to be deployed from fixed sites. An alternative would be to transport the missile components and assemble the pieces at the launch site, but this would involve a lengthy process at the launch site which could be tactically disadvantageous.

Due to its favorable geography, the threat to the United States does not appear likely to change much in the near term. New York, for example, is about 7500 km from Libya and almost 10,000 km from Baghdad. Of the three countries (Israel, India and Brazil) that are most likely to develop missiles with 5,000 km or greater ranges in the near term, India is the most likely to be at odds with the United States. Even if a conflict were to develop, the geography is such that the American targets nearest to India are more than 11,000 km away. It seems far more probable that India would concentrate its efforts on developing a 5000 km range missile capable of reaching targets in China rather spending its resources on a missile capable of striking the United States. There could be commercial trade in such long-range mis-

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4. "Libyan Scud B Attack on Lampedusa Island," *Jane's Defense Weekly*, April 26, 1986, p. 739.

siles, but presently only four countries are capable of producing such missiles (United States, the Commonwealth of Independent States, China and France). In contrast, shorter-range missiles could be launched at the United States from Central America, the Caribbean or even from offshore transport ships. This very real threat has existed for a long time but since it would likely be a one-time event (due to US counteraction) it has not been considered very seriously since the 1960s. However, as the capability to equip these missiles with nuclear or chemical warheads spreads, this threat may have to be reconsidered. China, of all the Third World countries, remains the principal missile threat to the United States in the near term. This is especially true because Chinese missiles are equipped with thermonuclear warheads. Although this danger has existed for more than a decade, the increased tension between the two countries since Tiananmen Square, plus the possibility of defending against the threat, may make it time to reconsider US ballistic missile defense options. This view is reinforced by the breakup of the Soviet Union, and the possibility of one or more of the former Soviet Republics becoming maverick nuclear powers.

IMPROVED CEP

Almost all of the ballistic missiles currently under development or in use in the Third World utilize inertial guidance and have CEPs in the 1-2 km range. Such a range of CEPs, as previously discussed, substantially limit the effectiveness of these missiles, especially when they are equipped with high explosive warheads. Improving the CEP would significantly increase the classes of targets that could be effectively attacked.

One way of achieving an improved CEP is to develop better inertial guidance. The MX missile reportedly has a CEP of less than 100 m, but Third World countries are unlikely to develop such an advanced guidance system and it is also unlikely that such a system would be allowed to be exported.[5] For less than ICBM range missiles, however, some improvement should be possible in the CEP obtained using inertial systems, especially if the technology can be obtained from more advanced countries. For

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5. Duncan Lennox, editor, *Jane's Strategic Weapon Systems*, Jane's Information Group, Alexandria, Virginia, 1990.

example, China is developing an M-9 missile with a reported CEP of 300 m for export. [6]

However, there are simpler ways of achieving improved CEPs. The Indian *Prithvi* employs command guidance, similar to a long-range Surface-to-Air (SAM) missile, as well as inertial guidance.[7] A ground site near the missile launch point tracks the missile and sends commands to correct its course. As a result the *Prithvi* is reported to have a CEP of 250 m.[8] Of course there are drawbacks to this approach. The need for the data link limits the missile's range to about 250 km. Also, it should be possible to try and jam the data link or attack the site sending the commands--but this may be beyond the capability of many Third World opponents. India has shown substantial ingenuity in this area and it is planning to begin large-scale production of this missile in 1992 for the Indian Army.[9]

Another way of improving accuracy--one which is likely to become widespread in the future--is to utilize a system like GPS or the CIS's *Glonass*. Even in its scrambled mode, GPS will provide a CEP of 100 m. The receivers are becoming cheap and lightweight. Third World ballistic missiles, however, are currently limited in their ability to use GPS to improve their accuracy. These missiles have neither post boost vehicles (PBV) nor maneuvering reentry vehicles (MARV). Therefore, these missiles have no way of correcting guidance errors after the main engine burnout--which occurs relatively early in the missile's trajectory. Velocity errors resulting from GPS plus the uncertainty in the fuel cutoff time, when combined with reentry errors, mean that even with GPS, the CEPs of short-range ballistic missiles will not be less than a few hundred meters (although a *Prithvi* type missile could do better). Further, since many of the errors increase with time, the CEPs of longer-range missiles using GPS will be even worse. On the other hand, if nothing else GPS should eliminate the need to launch from pre-surveyed sites.

GPS is an ideal guidance system for cruise missiles. Little public information exists on cruise missile developments in the Third World. However, Henry Sokolski, Deputy for Non-Proliferation Policy, US Department of Defense, has reported that there are over 100 cruise missile programs underway in

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6. *Ibid.*

7. Edmond Dantes, "Missiles in Gulf Buoy India's Development Drive," *Defense News*, February 25, 1991, p. 44.

8. *Jane's Strategic Weapon Systems, op. cit.*

9. Dantes, *op. cit.*

Third World countries.[10] With GPS, cruise missiles will have CEPs of 100 m, independent of range. Using differential GPS techniques, accuracies substantially better than 100 m may be possible. Such cruise missiles could pose the greatest new threat to the United States. Relatively short-range missiles fired from surface ships would be untraceable given the lack of radar coverage over the ocean and the ability of a cruise missile to "dog leg" as it flies to its target. Its accuracy could be such that a GPS-guided cruise missile could score a direct hit on the White House or the US Capitol.

WARHEADS WITH INCREASED LETHALITY

Nuclear

Equipping ballistic missiles with warheads with increased lethality will, of course, greatly increase the threat from such missiles. The combination of ballistic missiles and nuclear warheads has been one of the most important developments since World War II. There is a striking correlation between the nine countries that have autonomous ballistic missile programs (Table 3) and countries with nuclear weapons development programs. China, of course, has equipped its ballistic missiles with thermonuclear warheads. Four of the other countries listed in Table 3--Israel, India, Pakistan and South Africa--are considered to be *de facto* weapon states.[11] Recently Iraq has been found to be violating the Non-Proliferation Treaty (NPT) by, among other things, having a clandestine uranium enrichment program. Until recently Brazil had a nuclear weapons program which was shut down by Brazilian President Fernando Collor de Mello as part of his efforts to bring the Brazilian military under tighter civilian control. However, it is continuing to develop the facilities needed to produce nuclear material for a weapons program. As a result, if the Brazilian government should change its mind, it will be easy for them to produce nuclear weapons. Although North Korea has signed the NPT, it has built a plutonium production reactor and is building a reprocessing plant to separate the plutonium produced by this reactor. At the same time it

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10. Statement of Mr. Henry D. Sokolski, Deputy For Non-Proliferation Policy, Office of the Assistant Secretary Of Defense, International Security Affairs, US Department of Defense, before the Joint Economic Committee, Subcommittee On Technology And National Security, US Senate, April 23, 1991.

11. In July of 1991 South Africa signed the NPT and, moving rapidly, in September concluded a safeguards agreement with the IAEA. These steps along with promising political changes may indicate that South Africa is moving away from a nuclear weapon capability. On the other hand, if it keeps significant stocks of highly-enriched uranium, even if under IAEA safeguards, then it will retain the option to rapidly reacquire nuclear weapons.

delayed entering into the required safeguard agreement with the IAEA until early 1992, well past the 1988 deadline. It continues to drag its feet on allowing an actual inspection, leading some to believe that even its acquiescence to inspection is a delaying tactic designed to allow it to complete its weapon program.[12] Similarly Argentina, while denying the existence of a nuclear weapons development program, also has facilities for producing nuclear material which could make it easy for it to produce nuclear weapons.

While advanced nuclear powers have easily equipped their ballistic missiles with nuclear weapons, it remains to be seen whether less-advanced nuclear powers with little experience with nuclear testing can do the same. A primitive nuclear weapon of the Nagasaki type weighs 4.5 te and is 150 cm in diameter. Such a weapon could not easily be carried on the types of ballistic missiles that are the focus of concern here. It is likely that the initial success that countries will have in developing the smaller, lighter weapons needed for their ballistic missiles will vary by country. Evidence suggests that many of them will be successful. In the early 1950s the United States was able to equip a short-range *Corporal* ballistic missile with an early US nuclear weapon, the *Mark 7*.[13] China's fourth nuclear test was of a nuclear warhead specifically designed to be smaller and lighter than the nuclear weapon it had air-dropped for its second nuclear test.[14] The warhead, carried by a CSS-1 ballistic missile, was fired a distance of at least 800 km.[15] It detonated successfully, with an estimated yield in the low tens of kilotons. It was recently revealed that Brazil had a nuclear weapons program, with two nuclear weapons planned: one, a 20 kt device to be delivered by aircraft; the other, a 12 kt device intended to be delivered by a ballistic missile[16]

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12. Terrence Kiernan, "Critics Rap N. Korean Sincerity," *Defense News*, April 13-19, 1992, p. 36.

13. Thomas B. Cochran, William M. Arkin, Milton M. Hoenig, *Nuclear Weapons Databook, Volume I, U.S. Nuclear Forces and Capabilities*, National Resources Defense Council Inc., Ballinger Publishing Company, Cambridge, Massachusetts, 1984, p. 10.

14. Selections from the book *Modern China's Nuclear Industry*, edited by the DANGDAI ZHONGGUO [China Today] Series Editorial Committee. Reproduced in *JPRS Report--Science & Technology, China*, Foreign Broadcast Information Service, JPRS-CST-88-008, April 26, 1988, p. 8.

15. John Wilson Lewis and Xue Litai, *China Builds the Bomb*, SP 280, Stanford University Press, Stanford, California, 1988, p. 244.

16. Jose Eustaquio de Freitas, "Development of Solimoes Nuclear Project Detailed," *O GLOBO*, November 16, 1990, p. 15. Reproduced in *JPRS Report--Nuclear Developments*, Foreign Broadcast Information Service, JPRS-TND-91-001, January 4, 1991, p. 15.

which was to be based upon Brazil's Space Launch Vehicle and to have a range of 3000 km.

In addition, a number of Third World countries may already have experience with nuclear weapon design. India exploded a nuclear device in 1974. Israel was involved in the design and testing of early French nuclear weapons in the early 1960s.[17] Pakistan is reported to have received a tested nuclear design from China in the early 1980s, possibly the one used for China's fourth test involving a ballistic missile. South Africa may have tested a nuclear weapon in 1979, and, additionally, may have collaborated on nuclear weapon development with Israel.

A 10 kt warhead on a missile would have devastating effects on a city. In Tel-Aviv 50,000 people might be killed, with as many injured; in Tehran the fatalities could be on the order of 170,000. Against a variety of military targets, such a weapon would be quite effective if it scores a hit. However, against many point targets the effective radius of even a 10 kt weapon is only 1 to 2 km. With a CEP of about the same magnitude, a single weapon would only have about a 50 percent chance of destroying its target. Given that there is likely to be a limited number of nuclear weapons available, even with a nuclear warhead there is a need to improve the missile CEP to 500 m or less to achieve effectiveness against point targets.

Chemical

Twenty countries reportedly are pursuing chemical weapons programs.[18] Three countries of particular interest here are Iraq, Syria and Libya. Iraq has recently admitted that it has produced Mustard gas, and the nerve gasses Tabun and Sarin.[19] Syria is reported to have an advanced chemical weapons program and the ability to manufacture nerve agents.[20] Libya has built a large chemical production facility at Rabat and is assumed to be able to produce Mustard gas, at least, if not nerve gasses as

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17. Leonard S. Spector with Jacqueline R. Smith, *Nuclear Ambitions*, Westview Press, Boulder, Colorado, 1990, p. 152.

18. David B. Ottaway, "Libya Builds Huge Poison Gas Plant, CIA Chief Says," *Los Angeles Times*, October 26, 1988, p. A7.

19. Thalif Deen, "Iraq Declares its Missile Inventory," *Jane's Defense Weekly*, April 27, 1991, p. 677.

20. Colin Norman, "CIA Details Chemical Weapons Spread," *Science*, February 17, 1989, p. 888.

well.[21]

Iraq has also admitted that it had 30 chemical warheads for its *Al-Husayn* missiles although it did not specify what the chemical agent was. More recent inspections have found several missiles with nerve agent warheads.[22] Syria, reportedly since 1986, has had the capability to equip its *Scud-B* missiles with chemical warheads and will probably fit them on the Scud *PIP* that it recently received from North Korea as well.[23] These examples clearly demonstrate that it is not overly difficult for Third World countries to fit chemical warheads on short-range ballistic missiles. Some problems may arise, however. Optimally the warheads should be fused to explode at some distance above the ground to maximize the dispersal of the chemical agent. This requirement may be too great a challenge for some countries and their weapons may only be capable of exploding on impact, which would result in the chemical agent not dispersing as widely. Also for longer-range missiles, the increased reentry velocity will pose problems. There will be more reentry heating which could affect chemical agents. Similarly, the proper fusing necessary to achieve the most effective dispersal of the agent will be more difficult.

Modern nerve agents have never been used in urban areas and so the effects of such use are somewhat uncertain. To analyze what the consequences might be, consider the effect of one Scud filled with a volatile G-type agent (Sarin or Soman). Against unprotected people, the equivalent lethal area of such a warhead might be quite a large area--1 to 2 square km.[24] By contrast, the equivalent lethal area of a unitary high-explosive warhead is only 0.001 square km. The equivalent lethal area of the 15 kt weapon at Hiroshima, "Little Boy," was about 7.5 square kms.[25] Clearly, the lethal area of a chemical warhead is much closer to that of a nuclear one than to a high-explosive one. In fact, it is about the same

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21. David Lauter, "U.S. Steps Up Efforts to Halt Libya Gas Plant," *Los Angeles Times*, March 8, 1990, p. A1.

22. *Los Angeles Times*, April 20, 1991, *op cit.*, and interview with Rolf Ekeus, Executive Chairman, U.N. Special Commission on Iraq, *Defense News*, January 6, 1992, p. 30.

23. "Syria's Acquisition of North Korean 'Scuds,'" *op. cit.*, p. 250.

24. A Scud-carrying Soman would be able to cover about 1.6 square km with a vapor concentration of 5mg per cubic meter. Assuming a lethal dose of 70 mg-min per cubic meter, a lethal dose would be received in 14 minutes. See: *The Military Balance 1988-1989*, The International Institute for Strategic Studies, London, Autumn 1988, pp. 242-249.

25. Based on the number of fatalities and the population density. See Samuel Glasstone, *The Effects of Nuclear Weapons*, US GPO, Washington D.C., February 1964, p. 550.

as that of a 1 kt nuclear weapon. The fatalities from such an attack might be quite high especially if the population were not expecting a chemical attack. Depending on the city, fatalities might be in the thousands to tens of thousands. However G-agents, while very hazardous if inhaled, are not very dangerous otherwise. Therefore, with the judicious use of gas masks, as the Israelis did during the Gulf War, the equivalent lethal areas and, consequently, danger to the population, are significantly reduced--probably to below 0.01 square km.[26]

The effectiveness of chemicals against other fixed targets would be less, compared to nuclear weapons, than against cities for several reasons. First, military forces would be more likely to don gas masks and be trained in safety procedures for chemical attack than would the general population. Attacks on industrial facilities might kill some workers but would not damage equipment. Furthermore, attacking an installation like an airfield would require a CEP of less than a kilometer as well as up-to-date knowledge of winds at the target, though the latter may be deducible from weather satellites. Nonetheless, a chemical attack would still be more effective under most circumstances than an attack using high explosives.

Advanced Conventional

Several Third World countries have shown interest in equipping their ballistic missiles with improved high-explosive warheads--principally various kinds of submunitions. The Indian *Prithvi* will have different types of warheads permitting it to attack various battlefield targets.[27] At one time Brazil was considering equipping its SS-300 missile with various submunition warheads with anti-tank, anti-personnel or anti-fortification capabilities.[28] However this missile program appears not to be proceeding due to funding difficulties.

Estimates of warhead effectiveness indicate that submunitions might have up to ten times the

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26. Indeed the primary source of fatalities might be failure of a mask to be used or to work properly.

27. "Successful Test of Prithvi Missile Hailed," commentary by Ravinder Pal Singh, reproduced in *JPRS Report: Proliferation Issues*, Foreign Broadcast Information Service, JPRS-TND-91-012, August 8, 1991, p. 18.

28. Agusto Calton, "Brazil's Growing Missile Industry," *Jane's Defense Weekly*, March 5, 1988, p. 401.

lethal area of a unitary warhead.[29] While this is a significant improvement, the equivalent lethal areas are still quite small--on the order of 0.01 square km. With current CEPs, such missiles would still not be able to effectively attack point targets. Even for area targets it is not clear that the missiles could be used profitably. For example, one calculation showed that in an attack on an airfield it would take more than one missile to destroy an single aircraft.[30]

One type of improved munition that has been in the news recently is a fuel-air explosive. This munition works by dispersing a cloud of fuel which is then detonated. It can produce greater blast effects at certain distances than ordinary high explosives since it uses the air as an oxidizer and it detonates over an area rather than a point.[31] However, much of the damage from an ordinary high explosive is actually done by fragments from the bomb case rather than from the blast effects alone. Fuel-air explosives do not generate fragments. Additionally there are problems getting the fuel to disperse and ignite in an optimal way. As a result, even the United States and the Commonwealth of Independent States have made very little use of such weapons. Given the high-speed fuel dispersal problem, it seems unlikely that fuel-air explosives will be used on Third World ballistic missiles any time soon.

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29. David Rubenson and Anna Slomovic, *The Impact of Missile Proliferation on U.S. Power Projection Capabilities*, N-2985-A/OSD, The Rand Corporation, Santa Monica, CA, June 1990, Figure 15, p. 21.

30. *Ibid.*, Figure 12, p. 18.

31. Louis Lavoie, "Fuel-Air Explosives, Weapons, and Effects," *Military Technology*, September 1989, pp. 64-70.

SECTION VII:
VIEWS DOWNPLAYING MISSILE PROLIFERATION

Despite the lessons of the Gulf War, there are still those experts who think that the threat posed by missile proliferation has been overstated. This is the view of a Stanford University study.[1] Central to this view is the argument, based on technical considerations, that aircraft have much larger payloads than ballistic missiles have and, even after considering losses, aircraft are a much more efficient way to deliver high explosive, or even chemical, warheads.[2] This study recommends bringing export controls on ballistic missiles and on aircraft more "into balance". Their argument is that the spread of nuclear weapons should be the focus of our concern and that too much effort is being directed toward stopping missile proliferation. They believe that given the limited resources available to deal with issues of nonproliferation overall, such efforts would hinder attempts to stop the proliferation of weapons of mass destruction.

The events of the Gulf War certainly do not support this school of thought. Iraq's large modern air force, in contrast to its missiles, caused few problems for the Coalition. Aircraft-delivered bombs neither hit Tel Aviv or Riyadh nor did they achieve any military objectives. Seemingly their only role in the war was to serve as a target for Coalition air attacks. Furthermore, it can be shown that this result is likely to be typical rather than anomalous.

Critical to this assessment, however, are difficulties associated with aircraft operations that are not well captured in technical evaluations of aircraft and missiles. The key issue is that of defense penetration by aircraft. It is often stated that aircraft attrition rates are typically about two percent. Sometimes this statement is based on World War II experiences,[3] and other times on a selection of American

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1. *Assessing Ballistic Missile Proliferation And Its Control*, Stanford University, Center For International Security And Arms Control, June 1991.

2. One of the principal authors of the Stanford study, Uzi Rubin, has expressed similar views elsewhere. See Uzi Rubin, "Iraq And The Ballistic Missile Scare," *The Bulletin of the Atomic Scientists*, October 1990; Uzi Rubin "How Much Does Missile Proliferation Matter?," *Orbis*, Winter 1991.

3. See Fetter, *op. cit.* p. 9. For other reasons, however, Fetter is not sympathetic to the conclusion that considers aircraft to be more of a menace than missiles.

and Israeli experiences following World War II.[4] The World War II experiences, however, ignore the self-selection effect whereby the attacker avoids heavily-defended targets, while the post-World War II cases actually demonstrate the opposite of the conclusions usually drawn from them. This issue is of central importance to judging the significance of missile proliferation, as well as to air force planners in general. Therefore, a detailed examination of this question is warranted.

First it is necessary to accurately frame the attrition rates over a sustained campaign. For example, a two percent loss rate may sound almost insignificant, but actually it is about as high as can be tolerated. During World War II, American bomber crews had to fly 25 missions to complete their tour of duty and British crews had to fly 30. At a two percent loss rate, a crew would have only a 60 percent chance of completing 25 missions and only a 55 percent chance of completing 30 missions. At a five percent loss rate, there would be only a 28 percent chance of completing 25 missions, and only a 21 percent chance of completing 30. With a ten percent loss rate there would be only a seven percent chance of completing 25 missions and a four percent chance of completing 30. Indeed at this loss rate, there would be only a 48 percent chance of completing seven missions. At a 20 percent loss rate, the chance of completing just three missions would be 51 percent.

As we will see, loss rates between 10 and 20 twenty percent are not that uncommon but such loss rates obviously are not sustainable. Air forces which have encountered such defenses usually change their tactics or targets in order to lessen their risk. This brings the loss rate down to an acceptable level but at the cost of making the heavily-defended targets immune to attack.[5] Furthermore, at high loss rates the crews do not need mathematical calculations to see that their long-term survival chances are poor. Some crews attempt to improve the odds by not pressing home their attacks or even by deliberate-

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4. See, for example, *Assessing Ballistic Missile Proliferation And Its Control, op. cit.*, pp. 20-26, and David Rubenson and James Bonomo, *NATO's Anti-Tactical Ballistic Missile Requirements and Their Relationship to the Strategic Defense Initiative*, R-3533-AF, The Rand Corporation, Santa Monica, CA., December 1987, p. 7.

5. A variant of this response is for the aircraft to attack heavily defended targets only intermittently, while attacking less heavily defended targets and, therefore, less important targets the rest of the time. This tactic produces lower loss rates but also leads to a severe loss in effectiveness, since the long interval between attacks on the key targets allows these targets to recover from each attack.

ly dropping their bombs somewhere other than the intended target.[6]

In 1939-40 the British attempted daylight bombing against Germany. Because fighter aircraft of the period had a rather short range, bombers attacked without fighter escort. Five raids, consisting of 92 sorties, were attempted and sustained a 29 percent loss rate. As a result of this experience and for the rest of the war, the British changed from daylight to night bombing.[7] While this change in strategy greatly reduced the loss rate (at least temporarily), the bombings were far less accurate and, therefore, far less effective.

In August 1942 the American Air Force began its own daylight bombing effort.[8] Throughout 1942 it bombed only targets in Holland, Belgium and northern France--fighter protection could be provided against these targets. The loss rate during this period was 4.4 percent. Beginning in early 1943, the targets were expanded to include the fringes of Germany where fighter escorts could not be provided. This pattern of attack continued into July 1943. While the loss rate was still a tolerable 5.7 percent, military strategists recognized deeper penetrations into Germany where the unescorted bombers would be subjected to prolonged fighter attacks would be necessary in order to attack the most important targets. During the last week of July 1943 five deep-penetration operations were conducted into northern Germany. Not surprisingly, the loss rate jumped to 9.6 percent. Four deep penetration raids were conducted in August, some further inland than ever before. On August 1, the important oil center at Ploesti was attacked. The loss rate was 30.5 percent of the aircraft dispatched and no further attacks were made on this target until late spring of 1944. On August 17, the infamous Schweinfurt-Regensburg raid, which was the first deep penetration into southern Germany, took place. Of the aircraft which crossed the European coast, 16.6 percent failed to return. The average loss rate for the four deep-penetration missions in August was 16.4 percent. The overall loss rate for August was lower because a

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6. The British referred to crews that bombed at the earliest possible moment as "rabbits." As successive "rabbits" bombed, the aim point crept back away from the target. In an August 1943 Berlin raid, the aim point crept back more than thirty miles into open country. This was such a common phenomenon that British planners chose aim points on the far side of the target city so that as the bombing crept back it would still strike within the city.

7. Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Volume I, Her Majesty's Stationery Office, London, 1961, pp. 192-201.

8. This account is drawn from Martin Middlebrook, *The Schweinfurt-Regensburg Mission*, Viking Penguin Inc., New York, 1983, and from Wesley Frank Craven and James Lea Cate, *The Army Air Forces In World War II*, Volume Two, US Government Printing Office, Washington D.C., 1949.

number of short-range missions were conducted, all of which were within range of Allied fighter protection. However, it was recognized that flying such "milk-runs" exclusively would not win the war. The following month, despite generally poor weather, one deep penetration in clear weather was attempted against Stuttgart on September 6. Of the attacking force, 17.2 percent were lost and bad weather over Stuttgart prevented Allied aircraft from attacking their assigned targets. The climax of these raids occurred in October with four deep-penetration raids ending, on the 14th, with a return attack on Schweinfurt. The loss rate for this raid was 26.3 percent; the average for the four missions was 12.6 percent. In the words of the official US history: "For the time being, moreover, the Eighth Air Force was in no position to make further penetrations either to Schweinfurt or to any other objectives deep in German territory. ... The fact was that the Eighth Air Force had for the time being lost air superiority over Germany."[9] Actually the Eighth Air Force could not lose what it had never had--since the end of July it had attempted, but failed, to win air superiority over Germany. The Eighth Air Force would not attempt another deep penetration mission over Germany in clear weather again until mid-February 1944 when long-range fighter escorts had become available.

At nearly the same time the British night bomber force was experiencing a similar failure.[10] A phase of the British bomber war, generally referred to as the Battle of Berlin, occurred from November 1943 through March 1944. During this period 35 long-range missions during this period were flown into Germany, 16 of which targeted Berlin. Of 20,224 sorties flown, 1,047 aircraft were lost, for an average loss rate of 5.2 percent. The average number of British bombers available for operations that November was 864. This means that during these five months the equivalent of more than the entire bomber force at the start of this phase was lost. Remarkably the British were able to provide enough crews and aircraft so that in March the average number of available bombers actually rose slightly to 974. However, despite their valiant efforts to maintain their bomber force, they were facing a growing array of combat problems. An increasing fraction of their attacking force was failing to bomb the pre-selected targets.

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9. Craven and Cate, *ibid*, p. 705.

10. This account is drawn from Webster and Frankland, *op. cit.*, Volumes II and III.

There were a large number of reports of aircraft jettisoning their bombs over the North Sea and Denmark to avoid German defenses. Furthermore, the prevailing 5.2 percent loss rate meant that an average British bomber crew would survive only 13 of their 30-mission tour of duty. Consequently, this meant that over time an increasing proportion of the British crews were more and more inexperienced. Additionally, while the loss rate during this period averaged 5.2 percent it, in fact, had started lower and had risen steadily. In November 1943, the loss rate averaged 3.6 percent but for the final attack of this phase against Berlin on March 24th, the loss rate was 9.1 percent. The concluding attack in the Battle of Berlin was a disastrous raid on Nuremburg on March 30th. The loss rate was 11.9 percent and only a small fraction of the attacking force is believed to have bombed the target. At this point, the British bomber forces gratefully broke off the attack to bomb targets in France in preparation for the D-Day invasion. In the words of the official British history: "...in the operational sense, the Battle of Berlin was more than a failure. It was a defeat. The disastrous Nuremberg operation, ... brought the Bomber Command tactics of massed and concentrated attack against major targets to a dead stop and they were not again resumed until the entire air situation over Germany had been radically altered."[11] In the months that followed, the British occasionally attempted large raids into Germany but their loss rate remained high. In June there were three major operations over Germany with an average loss rate of 11.2 percent. Finally, in August 1944, several factors combined to lead to a collapse in Germany's night fighter effectiveness, including the loss of territory in western Europe which contained forward German fighter bases as well as radar early warning stations and a shortage of fuel due to air attacks against German oil production facilities. This allowed the British to resume major bomber operations against Germany while suffering only modest losses.

Certainly then World War II contains a number of examples of cases where the attrition rate against aircraft was much higher than the just two percent frequently cited as the typical rate of attrition. In the cases discussed here, the loss rate was greater than ten percent and the aircraft had to abandon attacks on these heavily defended targets until circumstances changed. But what of the experience since

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11. *Ibid*, Volume II, p. 193. British author Martin Middlebrook, who has interviewed many of the participants in these raids, provides valuable insight into the human toll of the Battle of Berlin. See Martin Middlebrook, *The Nuremberg Raid, 30-31 March 1944*, Allen Lane, London, 1973, and Martin Middlebrook, *The Berlin Raids*, Penguin Books, London, 1988.

World War II? The Stanford report cites a number of historical cases from the post-World War II period to demonstrate the opposite of our World War II examples. The cases they use to support their contentions were the 1965-68 US attacks against North Vietnam ("Operation Rolling Thunder"), the December 1972 US attacks against North Vietnam ("Operation Linebacker II"), Israeli air operations during the October 1973 Yom Kippur War, the June 1982 Israeli air attacks in the Bekaa Valley of Lebanon, and a preliminary analysis of Coalition air operations against Iraq during the Gulf War in early 1991. The loss rates of American and Israeli aircraft in these operations were at most a few percent and, typically, considerably less. But to cite these examples as the ultimate proof is to ignore what the problem of missile proliferation is really all about. The United States and Israel have the world's finest air forces. Various Third World countries may be able to buy advanced aircraft but they cannot purchase air forces of the caliber of the United States and Israel. Such air forces are made up of not only quality aircraft, but quality pilots as well. A pilot's skill is a key factor in determining the effectiveness of an airplane. American pilots flying in Korea and Vietnam, and Israeli pilots in various Arab-Israeli wars have run up very lopsided kill totals even though the aircraft being flown by the other side were technically similar or even superior in performance. The above examples, in fact, validate exactly the opposite of what the authors of the Stanford report intended. The North Vietnamese air force did not try to bomb targets in the South; had they, their losses would have been very high. The Syrian and Egyptian air forces suffered heavy losses in combat with Israel.[12] During the Gulf War, of the few Iraqi aircraft that attempted combat sorties, all appear to have been shot down. Based on these experiences, surely any Third World opponent of the United States or Israel would find missiles preferable to aircraft.

In the post World War II period there are not many well-documented cases of conflict where the competing air forces were more evenly balanced. One case that is reasonably well documented is the Falklands War in 1982.[13] Although accounts vary, it is clear that the attacking Argentines suffered

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12. For example, the Syrian Air Force suffered a 31 percent loss rate during the 1982 Lebanon War. See Karl Schnell, "Experiences of the Lebanon War," *Military Technology*, July 1984, p. 32.

13. Max Hastings and Simon Jenkins, *Battle For The Falklands*, W. W. Norton & Company, New York, 1983, and *Lessons Of The Falklands*, Summary Report, Department of the Navy, Washington, D.C., February 1983.

heavy losses. According to Argentinean statistics, their loss rate was about ten percent; according to British figures, it was over twenty percent. The reality, no doubt, is somewhere in between; the exact number is not that important since even a ten percent loss rate would have been crippling. This assessment is borne out by the actual events. In the first days of May, in an effort to preserve their air force, Argentina attacked only sporadically. They began all-out attacks when the British landed at San Carlos on May 21. By the end of May 25, the Argentines had sunk four British ships and damaged several others. But their air attacks could not be maintained in the face of heavy losses. There were reports that after attacking, Argentine aircraft were being sent to bases other than their home base to keep the Argentinean pilots from realizing the magnitude of their losses. Argentinean attacks became less frequent after May 25, and were not pressed home with the same determination as before. The British lost only one more ship (on June 8), and on June 14 the Argentine forces on the Falklands surrendered.

It might seem that this is a special case since the Argentine aircraft had the disadvantage of having to attack at almost the limit of their range, and their lack of fuel greatly limited the tactics that they could use. But the British faced a number of problems as well. Initially the two small British carriers had only 20 *Harrier* aircraft. This meant that only four to six aircraft could be airborne at any one time to intercept an attack. The *Harriers* themselves were hardly designed as air superiority aircraft and their need for vertical takeoff limited their range and payload. The British also lacked long-range early warning and their ships presented the Argentines with a small number of high-value targets which increased British vulnerability to air attack. Furthermore, only two British ships were equipped with the *Sea Wolf* anti-aircraft missile system for making intercepts at low altitude. So, clearly, both sides were operating under difficult conditions--difficulties which tended to balance themselves out.

This discussion, thus far, has referred only to the attrition suffered once the aircraft were airborne. But as was demonstrated again in the Gulf War, aircraft which operate from large, fixed facilities are much more vulnerable to being attacked on the ground than mobile missiles are. As discussed previously, the Iraqi missiles were quite hard to locate on the ground even though the barren terrain in Iraq was favorable for such an effort.

These examples demonstrate that defense effectiveness can often exceed the ten percent attrition rate needed to stop aircraft from effectively carrying out their mission. Therefore, what occurred

during the Gulf War is not unusual. Third World countries are likely to have both aircraft and long-range missiles, but as in the Gulf War, it is the missiles that, in most cases, will pose a more serious threat.

Thomas McNaugher, of the Brookings Institution, also has expressed views downplaying the missile threat similar to those of the Stanford study.[14] In addition, he has made a number of other arguments belittling the importance of Third World missiles. He believes that missile attacks had little to do with Iran's collapse of will at the end of the Iran-Iraq War, attributing it instead to other ongoing, adverse events. He further argues that even with chemical warheads, missiles would not be very dangerous. Populations could always protect themselves with gas masks, and even if not protected the effective lethal area of such missiles would be less than 0.1 square km, which he thinks would make the effects more like high explosives than nuclear weapons. Also he believes that with chemically-armed missiles, countries can easily develop a secure second-strike capability and, therefore, a stable balance of terror.

Any particular event always occurs embedded in a host of other events and, by itself, it is often difficult to determine its exact effect. This is where historical analysis is important in helping to ascertain the link between cause and effect. We have shown that serious psychological effects resulted from the German *V-2* attacks on London, from the Iraqi missile attacks on Tehran, and from the Iraqi missile attacks during the Gulf War. The impact of these psychological effects is modified by other contemporaneous events. In the case of London during the Second World War, these other events--such as the fact that England was winning the war--tended to cut the other way and helped to ensure that the *V-2* attacks did not seriously affect the war effort. In the case of Iran, as McNaugher states, there were a number of other adverse events that occurred around the same time as the Iraqi missile attacks on Tehran. The combined result was that Iran decided that it was time to end the war. During the Gulf War these psychological effects were again modified by other factors which were different in the two separate countries under Iraqi missile attacks. In the case of Saudi Arabia, it was already committed to confronting Iraq, and its people endured the attacks with little problem. In the case of Israel, however, it was not directly involved in the conflict and was strongly motivated to strike back at Iraq. This created

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14. Thomas L. McNaugher, "Ballistic Missiles and Chemical Weapons," *International Security*, Fall 1990.

political problems for the Coalition since it was possible that some of the Arab partners, in particular Syria, might drop out if Israel joined the conflict against Iraq. Therefore, the Coalition expended numerous air sorties attempting to suppress the Iraqi missile threat. These air sorties were far more numerous than simple military considerations would have dictated. And by diverting resources they caused a delay in attacks on other targets which impeded the start of the ground war against Iraq. Furthermore, these air attacks against the missiles were, at best, only partially successful.

With regard to chemical weapons, McNaugher is overly sanguine. Even if a chemical warhead's effective lethal area were only 0.1 square km, this would be about 100 times as effective as high explosive warheads and likely would kill hundreds of people per warhead if used against unprotected urban populations. Furthermore, as was shown above, chemical warheads might well have effective lethal areas in the 1-2 square km range which would mean thousands of fatalities per warhead and an effectiveness only somewhat less than that of a 10 kt nuclear warhead.

Before the Gulf War it was hoped that deterrence would prevent missile attacks. Some analysts and others have suggested that Iraq's attacks on Israel represent a failure of deterrence and demonstrate that not all nations are "rational actors". Actually the Gulf War experience represents a failure of simplistic academic models of deterrence of the "Country A, Country B" type. In such models the world consists of only two countries, A and B. As these bland designators indicate, there is no significant difference between A and B, and each is equally concerned with the possibility of attack from the other. Reality, however, is quite different. The Gulf War pitted a large coalition of nations against Iraq and one of their primary concerns was to prevent Iraq from attacking Israel, who was not a member of the Coalition. Iraq's attacks on Israel were clearly its rational attempt to goad Israel into attacking Iraq, thereby presumably creating dissension among the Coalition members. Certainly, once the Coalition started attacking Iraq with thousands of air sorties daily, the threat of additional Israeli attacks would not seem very significant.

Even when countries are armed with nuclear weapons, missiles are still a greater problem than aircraft are. If Iraq had nuclear weapons, it is clear its aircraft would not have been able to penetrate Coalition defenses to deliver them; and, with the rapid destruction of the Iraqi air force, even the threat of an air-delivered nuclear attack would have quickly disappeared. By contrast, even with the *Patriot*

defenses, missiles remained a threat since the *Patriots*, in some cases, did not intercept the missiles, and in a number of cases of intercept, the warhead remained intact. There would also be the possibility that, in light of the relatively small coverage area provided by the *Patriot*, the missiles could be used to attack undefended targets. Also, even with the Coalition's very intense effort to destroy the mobile missiles, a large number of missiles survived the war.

Thus there are sound reasons for considering the issue of missile proliferation as more pressing than the proliferation of advanced aircraft. Without question, the top nonproliferation priority must be the effort to stop or otherwise neutralize the spread of nuclear weapons. If efforts to stop missile proliferation were to diminish the effort to halt nuclear proliferation then that, indeed, would be undesirable. However, the total effort and resources presently committed to stopping various forms of world-wide proliferation is not considerable. Those of us who have been concerned with missile proliferation have wanted not a shift from efforts directed against nuclear proliferation, but rather an increase in non-proliferation efforts including missile proliferation. Indeed since many countries which are trying to obtain nuclear weapons seem to consider missiles as a preferred delivery means, efforts to impede missile proliferation may slow nuclear proliferation as well.

SECTION VIII:
SUMMARY AND CONCLUSIONS

Iraq's use of ballistic missiles during the Gulf War has reconfirmed the dangers associated with missile proliferation. Iraq used its missiles effectively in attacks on urban areas to produce psychological effects which, in turn, directly affected the Coalition's military operations through its need to try to suppress the Iraqi missile attacks. That missile attacks on urban areas could have significant psychological effects is supported by the experiences of London during 1944-1945 and of Tehran in 1988. In contrast, Iraq's modern Air Force played virtually no part in the Gulf conflict. This result corresponds to historical experience which has demonstrated that aircraft are ineffective when faced with attrition rates of greater than ten percent. Clearly it is easier for countries to buy a strike capability using missiles rather than aircraft against forces that can field effective air defenses (such as those of United States or Israel).

The principal Iraqi missile used during the Gulf War appears to have been the *Al-Husayn*. Iraq did not use any missile with a 850-900 km range (the nominal range of the *Al-Abbas*). If the *Al-Abbas* or the *Al-Hijara* were used at all, their characteristics must be similar to those of the *Al-Husayn*. All of the Iraqi missiles used during the war had unitary high explosive warheads and seem to have had a CEP of roughly 2 km.

The number of fatalities caused by the Iraqi missile attacks was about one-fifth to one-third of what might have been expected based on the characteristics of the *Al-Husayn* missile and the size and population of the targeted cities. One likely reason for this was the use, for the first time in combat, of a missile defense system--in this case the *Patriot*. It is hard to quantify, simply based on the reduction in fatalities, just how effective the *Patriots* might have been; there seem to have been other unknown factors responsible for the varying success of the *Al-Husayn* attacks on the targeted cities. However, the low number of damaging hits that occurred at Riyadh are hard to explain without at least positing a moderately effective *Patriot*. The dispute over the percentage of *Al-Husayn* warheads destroyed by the *Patriots*, if it can be resolved, might permit the *Patriot's* effectiveness to be directly determined. Certain-

ly it is clear that there is no evidence that the *Patriots'* use in Israel was counterproductive, as was asserted by Theodore Postol in his widely-reported congressional testimony. Postol's analysis contains serious methodological and arithmetical errors.

The characteristics of the *Al-Husayn* are typical of most of the missiles currently possessed by Third World countries. There are currently nine Third World countries with autonomous ballistic missile programs. Only two of these nine countries had tested a missile before 1984--another sign of the remarkable growth of such programs. Moreover, these programs will provide additional sources of missiles to the Third World. Third World countries will also try to acquire technology from the advance industrialized countries in order to improve their systems' capabilities beyond that of the *Al-Husayn* type of missile. The sought-after improvements will be in three areas: increasing missile range; significantly improving missile CEP; and, equipping the missiles with more lethal warheads than just simple unitary high explosive warheads.

Of the nine countries with autonomous missile programs, seven involve the development of missiles with ranges greater than the 600 km *Al-Husayn*. In addition, Saudi Arabia has acquired the CSS-2 missile with a 2,800 km range from China. Most of these systems have ranges of less than 3,000 km and, even with further developments, probably will not exceed 5,000 km. Therefore, these missiles are not likely to change the threat to the United States proper; more likely they will be a problem in the theater and for Europe.

Almost all of the ballistic missiles currently under development or in use in the Third World utilize inertial guidance and have CEPs of approximately 1-2 km. The need to improve weapon effectiveness will lead countries to try to improve missile accuracy. Countries such as China have inertial systems capable of 300 m CEP and they may be willing to provide their technology to other nations. The deployment of systems such as GPS and the Soviet *Glonass* open up the possibility of many countries having ballistic missiles with accuracies in the 200-400 meter range. Furthermore a system like GPS makes long-range cruise missiles with CEPs of less than 100 m feasible. Such cruise missiles would be able to seriously threaten targets in the United States.

There is a strong correlation between countries that have autonomous ballistic missile programs

and ones with nuclear weapons development programs. A primitive nuclear weapon of the Nagasaki type could not be carried on the types of ballistic missiles currently being developed by Third World countries. However, based on the history of the current nuclear powers and on recent developments in some Third World countries, it is likely that many such countries will be able to manufacture nuclear weapons small enough and light enough to be carried on ballistic missiles. These weapons could have yields in the low tens of kiloton range and, with a lethal area of almost 10,000 times that of a unitary high-explosive warhead, they could kill 50,000 to 170,000 people depending on the target. Iraq's recent admission that it had chemical warheads for its *Al-Husayn* missiles is a clear indication that Third World countries are able to equip their ballistic missiles with chemical warheads. The lethal area of chemically armed missiles would be roughly 100 to 1,000 times that of a missile with a unitary high explosive warhead and might kill between 500 and 10,000 people if used to attack a city where the population lacked chemical protection equipment. In contrast, advanced conventional munitions would probably only increase the lethal area by a factor of ten. With current CEPs, such missiles still could not effectively attack most targets, but if CEPs of less than 100 m become available, then advanced conventional warheads will have far greater military utility.

Since the threat from missiles is serious and steadily growing worse, steps need to be taken now to curb this danger. The Persian Gulf War experience has demonstrated that "deterrence" especially the sort described in academic discussions of "second strike" capability using "Country A, Country B" type models, cannot be relied upon to protect against missile attack. The real world of many countries and, in particular, the Middle East is much more complicated than such discussions would suggest. Iraq attacked Israel repeatedly despite the fact that Israel could have retaliated more powerfully either with missiles or aircraft. Once the Coalition had started attacking Iraq with thousands of air sorties a day, however, Iraq had little to lose and perhaps much to gain by attacking Israel.

The Gulf War experience has also demonstrated the difficulty in trying to suppress a missile threat once a conflict begins. In this most recent example, a significant number of the air sorties needed to prepare for the ground war were diverted to hunt for Iraq's mobile missiles. Yet their missile attacks continued right up until the end of the war, and Iraq's postwar declarations indicated that it still had 52 missiles. Roughly half of even the fixed missile launch sites survived the war despite the US announce-

ment in military briefings that all of them had been destroyed early in the war. This inability to locate the launchers occurred even though Iraq's barren terrain certainly provided a relatively favorable environment for the hunt.

The MTCR, by preventing the spread of missile technologies, would seem to be the most cost-effective way of dealing with the missile threat. The MTCR has helped to constrain ballistic missile programs in Brazil and Argentina, but has been only partially effective in other parts of the world.[1] However, now that Iraq's use of ballistic missiles has emphasized the dangers of missile proliferation and has embarrassed those countries involved in helping Iraq develop advanced weapons, it should be possible to enforce the MTCR guidelines more vigorously and the restrictions will be more effective as more and more countries abide by the MTCR guidelines. It will be particularly important for China and the former republics of the Soviet Union to support these guidelines. Given the number of autonomous missile programs, one might assume that it is too late to stop the spread of technology to these countries. Most of the countries with autonomous missile programs, however, have relatively short-range, inaccurate missiles and currently are attempting to improve their range and accuracy. By preventing these countries from receiving advanced technology, the MTCR can significantly delay these programs.

Active defenses are going to be very important in order to counter missiles that are already deployed. During the Persian Gulf War the *Patriot* showed an impressive capability to intercept attacking ballistic missiles. However, it is also clear that the current *Patriot* system has only a limited capability to destroy the missiles it intercepts and it will not be able to intercept longer-range missiles which would be traveling much faster on reentry. Future defensive systems must have greater capabilities. There are plans to improve the *Patriot* system and SDIO is developing five additional ground-based interceptor systems as well as the space-based Brilliant Pebbles. It should be possible to fashion a satisfactory network of defenses from these programs. Such a system should have a "hit-to kill" capability to ensure a high target kill probability. It will also need to be able to defend a larger area than the *Patriot* can and it

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1. That the MTCR was hampering the Brazilian missile program was the opinion of Jayme Boscov, the chief of Brazil's Satellite Launch Vehicle program. See "Obstacles to VLS Development Reviewed," *FOLHA DE SAO PAULO*, July 14, 1989, p. G-3, as reproduced in *JPRS Report: Nuclear Developments*, Foreign Broadcast Information Service, JPRS-TND-89-016, August 14, 1989, p. 20.

should make its intercepts higher in the incoming missile's trajectory in order to defeat countermeasures and chemical warheads.

Third World programs to increase missile range will cause an increased threat in the theater of conflict and to Europe. In the near term, at least, these systems will not be able to reach the United States proper unless they are launched from Central America, the Caribbean or from offshore transport ships. Nevertheless, with the spread of technology for nuclear and chemical weapons, the United States may need to take this threat seriously. With the development of defensive systems, this may be the time to consider a ballistic missile defense for the United States, especially in light of the increase in tension between the United States and China following Tiananmen Square and the ongoing upheavals in the former Soviet Union.

The Gulf War experience also demonstrated that there are serious shortcomings in US intelligence regarding missile and other types of proliferation in the Third World. These shortcomings were apparent--at least to some degree--even during the war. But it was only after the war, as the UN teams searched through Iraq, that the full extent of the West's ignorance become apparent. The completely unknown calutron uranium enrichment project is only one example. What is worse is that, at high levels of decision-making, there seems to have been an attitude during the Gulf War that anything that the United States did not know about, did not exist and, therefore, could not be harmful. This remarkable attitude was held despite the fact that it was known that very little attention had been paid to Iraq in the years prior to the war. It should have been obvious that the few months of intense pre-war scrutiny could not make up for years of neglect. Clearly the United States now needs to begin now devote much more intelligence effort to tracking these technologies in the Third World in order to help curb their proliferation, and, if conflict should occur, so that it will have a much better idea of its adversary's capabilities.

APPENDIX I: IRAQI BALLISTIC MISSILES

SCUD-B:

The *Scud-B*, developed by the Soviet Union, was first deployed in 1961.[1] With a range of 300 km and a conventional high-explosive warhead of 1000 kg (see Table 4), it uses inertial guidance to achieve a CEP of 1.0 km.[2] The unfueled missile, weighing approximately two 2 tonnes, is carried on an 8 x 8 wheeled transporter-erector-launcher(TEL) which has significant off-road capability. The missile can be fueled and launched in 90 minutes. Before the outbreak of the Iran-Iraq war in 1980, the Soviets had delivered a number of Scud-Bs to Iraq and they may have made additional deliveries during the war. In total, it is believed that Iraq has received approximately 800 *Scud-Bs*.

AL-HUSAYN

In 1987 Iraq claimed that it had developed an extended-range version of the *Scud-B*.[3] The West was skeptical about this claim until 1988. With the Iraqis bombarding Tehran (which is more than 400 km from the Iraqi border), the existence of this extended-range missile could no longer be denied. However, it is not known exactly how the Iraqis managed to extend the range of the basic *Scud-B*. Until the beginning of the recent Gulf War, the best information came from a 1988 sermon by Ali Akbar Rafsanjani (the current president of Iran) describing Iranian analysis of Iraqi missile debris. According to this analysis, the Iraqis apparently downsized the warhead and extended the fuel tanks. The warhead weight has been reported to be between 300 and 500 kg containing between 135 and 300 kg of high explosive. Examination of missile debris in Israel and Saudi Arabia, including a reported unexploded warhead as well as any captured missiles, should shed some light on this. The CEP of the *Al-Husayn* is

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1. A good article on the *Scud-B* is Steven Zaloga, "Ballistic Missiles in the Third World--Scud and Beyond," *International Defense Review*, November 1988.

2. *Ibid.*

3. The best article on Iraq's missile programs is: W. Seth Carus and Joseph S. Bermudez, Jr., "Iraq's *Al-Husayn* Missile Programme," *Jane's Soviet Intelligence Review*, Part 1, May 1990, Part 2, June 1990.

TABLE 4

BALLISTIC MISSILES IN IRAQ

MISSILE	RANGE (km)	PAYLOAD (kg)	CEP (km)	STATUS
SCUD-B	300	1,000	1.0	Used in combat
AL-HUSAYN	600-650	300-500	0.5-3.2	Used in combat
AL-ABBAS	700-900	300-1,000	0.3-4.8	Tested
SS-12	900	1,000	0.7	Not Obtained from Soviet Union
CONDOR II	900	500-1,000	0.6	Iraq no longer involved in development
TAMMUZ-1	2,000	750	N/A	First stage tested
AL-HIJARA	N/A	N/A	N/A	Used in combat

uncertain. The Iraqis claim a CEP of 0.5 km,[4] but other published values are larger, ranging up to 3.2 km.[5] As discussed earlier in the text, the Gulf War experience suggests an estimated CEP of 2.0 km. The Iraqis have developed the Al-Waleed TEL (based on the Saab-Scania tractor-trailer) assembled under license in Iraq, for the *Al-Husayn*. The Iraqis used over a hundred of these missiles in the Iran-Iraq war, and it appears to have been the principal missile they employed during the Gulf War.

AL-ABBAS:

On April 25, 1988 Iraq tested an extended-range version of the *Al-Husayn* known as the *Al-Abbas*. It was developed too late to be used in the Iran-Iraq war and, therefore, little is known about this missile. Its range is uncertain, estimates are between 700 and 900 km, and its warhead weight is reported to be between 300 and 1000 kg. By most estimates, the *Al-Abbas* has a heavier warhead than the *Al-Husayn*. How the missile could have both a longer range and heavier warhead is still uncertain. However, an *Al-Abbas*, exhibited at an Iraqi arms fair in 1989, was a further stretched version of the basic *Scud-B* missile. The Iraqis claim a CEP of 0.3 km, but other published values are larger, ranging up to 4.8 km. Like the *Al-Husayn*, it uses the Al-Waleed TEL. As was discussed in the text, there does not seem to be any evidence that the *Al-Abbas* was used in the Gulf War; therefore, one must question whether the *Al-Abbas* was ever produced.

SS-12:

There have been repeated reports that Iraq may have received some SS-12s from the Soviet Union. This missile, first deployed by the Soviets in the 1960s, has a 900 km range, a 1000 kg warhead, and a CEP of 0.7 km. If Iraq had received this missile in quantity, it would not have needed to embark on its *Al-Husayn* missile program. The fact that Iraq developed the *Al-Husayn*, plus the fact that there does

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4. Guy Willis, "Open Sesame! Baghdad Show Reveals Iraqi Military-Industrial Capabilities," *International Defense Review*, June 1989, p. 837.

5. *CRS Report for Congress*, "Missile Proliferation: Survey of Emerging Missile Forces," Congressional Research Service, February 9, 1989 p. 39.

not seem to be any evidence that SS-12s were used in the Gulf War, suggests that the Soviets never provided Iraq with SS-12s.

CONDOR II:

There also were a number of reports that in the late 1980s Argentina, Iraq and Egypt were involved in the development of a missile. This missile, the *Condor II*, was reported to have a range of 900 km and a warhead weight of between 500 and 1000 kg. The Argentineans, while admitting that their Air Force was developing such a missile, denied that they were cooperating with Egypt or Iraq. In fact, until recently, they claimed that the project was developed only for peaceful purposes. However, their statements have hardly been consistent. In 1989 when asked whether the *Condor II* was a missile or a satellite-launching project, Argentinean Air Force Chief of Staff Brigadier Jose Antonio Julia said "It is a propulsion unit capable of carrying a load to a specific distance and it can be adapted to any situation."[6] In April 1990, the Argentineans announced that they were suspending the project due to a shortage of funds, while continuing to maintain that it was for peaceful purposes only.[7] However, in May 1991 they announced that the earlier suspension referred only to the military part of the project, and that the peaceful component would continue under the aegis of their national space agency (an Air Force organization).[8] Regardless of whatever all these statements mean with regard to the *Condor II* missile itself, the participation of Egypt against Iraq during the Gulf War as well as Argentina's embarrassment as a possible source of missile technology for Iraq, suggests that Iraq is no longer involved in the *Condor II* project.

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6. TELAM, October 10, 1989. Reproduced in *JPRS Report: Nuclear Developments*, Foreign Broadcast Information Service, JPRS-TND-89-020, October 26, 1989, p. 22.

7. Statement by Argentine Defense Minister Humberto Romero. TELAM April 27, 1990. Reproduced in *JPRS Report: Nuclear Developments*, Foreign Broadcast Information Service, JPRS-TND-90-009, May 15, 1990, p. 9.

8. Statement of Defense Minister Erman Gonzalez. NOTICIAS ARGENTINAS, May 13, 1991. Reproduced in *JPRS Report: Nuclear Developments*, Foreign Broadcast Information Service, JPRS-TND-91-008, May 31, 1991, p. 18.

TAMMUZ-1:

Iraq tested a new missile on December 5, 1989. In a clear demonstration of the dual nature of missile technology, Iraq announced that this missile could serve as either a satellite launch vehicle or as a 2000 km range ballistic missile. The satellite launch vehicle was called the Al-Abid and the ballistic missile was named the *Tammuz-1*. The warhead weight of the *Tammuz-1* is estimated to be 750 kg. Apparently only the first stage of this missile, thought to be five *Al-Husayns* bundled together, was tested. Since Iraq is to small to test a 2000 km missile within its borders, apparently it tried in the summer of 1990 to acquire a launch site in Mauritania so that it could test the *Tammuz-1* into the Atlantic Ocean.[9] Presumably the embargo against Iraq in August 1990, and the subsequent Gulf War presumably stopped the development of this missile.

AL-HIJARA:

In the fall of 1990 Iraq announced that it had developed the *Al-Hijara* missile with a range of hundreds of kilometers.[10] No other details were given. During the Gulf War Iraq announced that this missile had been fired at Israel. Presumably this missile is a variant of the *Al-Husayn*, although the differences are not known.

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9. Joseph S. Bermudez, Jr., "Feedback--Iraq," *op. cit.*

10. *Jane's Defense Weekly*, October 1990, p. 744.

APPENDIX II:
CRITIQUE OF POSTAL'S ASSERTIONS OF THE COUNTER-PRODUCTIVE PERFORMANCE OF *PATRIOT* MISSILES IN ISRAEL

In April 1991, Theodore Postol, in widely-reported testimony before the US Congress, suggested that in Israel the *Patriot* missiles were actually counterproductive, causing more damage and injuries than they prevented. In brief, he testified that before the *Patriots* arrived in Israel there were 13 "Scuds" (actually *Al-Husayns*) that "fell in the Tel Aviv area" and, based on a chronology in the Tel Aviv newspaper *Ma'ariv*, these missiles caused no deaths, 115 injuries and damaged 2698 apartments (see Table 5). After the *Patriots* arrived there were only 11 "Scuds" yet they caused one death, injured 168 and damaged 7778 apartments.[1] The ratio of casualties per missile would, therefore, actually have increased after the *Patriots* arrived by a factor of 1.74 and the ratio of damaged apartments per missile increased by a factor of 3.41 when compared to the time before the *Patriots* arrived. He concluded, "The data suggests that the defensive operations could well have increased the net level of ground-damage relative to the case of no defense."[2]

However, there are several problems with Postol's analysis. The number of damaging hits in Tel Aviv in the "before-*Patriot*-arrived" case is only four and only five in the "after-*Patriot*-arrived" case. Combining these small sample sizes with the highly skewed distribution of damage per missile hit (discussed in the main text) would mean that even if the data were as Postol presented it, it would still be hard to assert that the difference between the two cases was statistically significant.

But, in fact, Postol's presentation of the data actually contains important errors. Using the *Ma'ariv* chronology that Postol (which basically agrees with other chronologies) used, one finds that there were only 11 "Scuds" (not 13, Postol erroneously added two missiles which struck Haifa) which landed in

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1. Theodore A. Postol, "Lessons for SDI from the Gulf War PATRIOT Experience: A Technical Perspective," Testimony Before the House Armed Services Committee, April 16, 1991. Typescript provided by the author.

2. *Ibid.* Elsewhere in his testimony Postol more cautiously stated: "The public data suggests that the undefended situation could have resulted in ground damage that might well have not been substantially worse than that from the defended situation." However, his provocative conclusion that the use of *Patriots* might have been counterproductive is the one that was widely reported by the media and would seem to be the logical conclusion from his analysis.

TABLE 5

POSTAL APRIL 1991 PRESENTATION OF MA'ARIV CHRONOLOGY OF THE EFFECTS OF THE MISSILE ATTACKS ON ISRAEL DURING THE GULF WAR COMPARED WITH THE ACTUAL MA'ARIV CHRONOLOGY

Cities	No. of Missiles	No. of Deaths	No. of Injuries	No. of Damaged Apartments	Ratio of "After-*Patriot*-Arrived" Case Compared to the "Before-*Patriot*-Arrived" Case: Casualties per Missile	Ratio of "After-*Patriot*-Arrived" Case Compared to the "Before-*Patriot*-Arrived" Case: Damaged Apartments per Missile
POSTAL–BEFORE *PATRIOT* ARRIVED}						
Tel Aviv	13	0	115	2,698 }		
					1.74	3.41
POSTAL–AFTER *PATRIOT* ARRIVED }						
Tel Aviv	11	1	168	7,778 }		
ACTUAL MA'ARIV CHRONOLOGY–BEFORE *PATRIOT* ARRIVED}						
Tel Aviv	11	0	115	2,698 }		
					0.84	1.52
ACTUAL MA'ARIV CHRONOLOGY–AFTER *PATRIOT* ARRIVED }						
Tel Aviv	20	1	174	7,429 }		

the vicinity of Tel Aviv before the *Patriots* arrived. Furthermore, there were 20 "Scuds" (not 11) which landed in the general Tel Aviv area after the *Patriots* arrived in Israel.[3] This correction along with other more minor corrections would change the ratio of injuries per missile in the "after-*Patriot*-arrived" case to 0.84 (i.e., a decline) and the ratio of damaged apartments per missile to 1.52 when compared with the "before-*Patriot*-arrived" case (see Table 5). Now when one considers the small sample size and skewed damage distribution it is clear that no case can be made that the *Patriot* actually increased the injuries and damage in Israel after it was deployed.

Given these problems it is not surprising that in a more recent publication Postol retreated from his earlier position that the damage in Israel was more severe after the *Patriot*'s arrival than before its arrival.[4] But rather than acknowledge his retreat, he attempts to mask it by changing his analysis in a way that lacks a methodological basis. Nor has he improved his arithmetic.

Postol now recognizes that the 13 missiles that struck Israel before the *Patriots* arrived included two that hit Haifa as well as 11 that landed in the Tel Aviv area. But rather than simply using 11 instead of 13, his analysis now includes Haifa. This creates several new problems in his assessment, not the least of which is that he has not changed his damage figures to include the damage at Haifa (there were no casualties from any of the missile attacks on Haifa--see Table 6). For the "after-*Patriot*-arrived" case Postol counts only those missiles actually engaged by the *Patriots*--a number he estimates at between 14 and 17. With these changes, the ratio between the "after-*Patriot*-arrived" case and the "before-*Patriot*-arrived" case is between 1.12 and 1.36 per missile for casualties, and between 2.21 and 2.68 per missile for damaged apartments. Postol now recognizes that this data is not statistically significant but, nevertheless, he thinks the fact that the ratio of casualties increased by "almost 50 percent" and the number of

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3. This is based on the *Ma'ariv* chronology from Postol's congressional testimony. The 11 missiles which struck before the *Patriot's* arrival were reported by *Ma'ariv* to have landed in Tel Aviv proper and central Israel. The 20 missiles after the *Patriot's* arrival were reported to have hit Tel Aviv proper, central Israel, and Gush Dan, which is the urban area surrounding Tel Aviv.

4. Postol, "Lessons from the Gulf War PATRIOT Experience," *op. cit.*. This article contains a translation of the *Ma'ariv* chronology. Unfortunately it contains two errors. It indicates that on January 26, three missiles hit in the vicinity of Haifa when in fact there was only one and on February 25, it indicates that only one missile hit in southern Israel when in fact there were two. Postol's congressional testimony contains a photocopy of the *Ma'ariv* chronology and we have used this as the basis of our analysis.

TABLE 6

REVISED POSTAL PRESENTATION OF MA'ARIV CHRONOLOGY OF THE EFFECTS OF THE MISSILE ATTACKS ON ISRAEL DURING THE GULF WAR COMPARED WITH THE ACTUAL MA'ARIV CHRONOLOGY

Cities	No. of Missiles	No. of Deaths	No. of Injuries	No. of Damaged Apartments	Ratio of "After-*Patriot*-Arrived" Case Compared to the "Before-*Patriot*-Arrived" Case: Casualties per Missile	Ratio of "After-*Patriot*-Arrived" Case Compared to the "Before-*Patriot*-Arrived" Case: Damaged Apartments per Missile
POSTAL–BEFORE *PATRIOT* ARRIVED}						
Tel Aviv & Haifa	13	0	115	2,698 }		
					1.12 - 1.36	2.21 - 2.68
POSTAL–AFTER *PATRIOT* ARRIVED }						
Tel Aviv & Haifa	14-17	1	168	7,778 }		
ACTUAL MA'ARIV CHRONOLOGY–BEFORE *PATRIOT* ARRIVED}						
Tel Aviv & Haifa	13	0	115	2,798 }		
					0.82	1.75
ACTUAL MA'ARIV CHRONOLOGY–AFTER *PATRIOT* ARRIVED }						
Tel Aviv & Haifa	24	1	174	9,029 }		

damaged apartments "tripled" provides "considerable food for thought".[5]

But this more recent analysis has as many problems as the first. The most important one is that in the "before-*Patriot*-arrived" case he counts all of the missiles that hit Israel whereas in the "after-*Patriot*-arrived" case he includes only those missiles that were engaged by the *Patriots*. But a number of the missiles not engaged by the *Patriots* must have landed outside the defended areas. Such missiles would have been the less accurate ones and probably did not cause any damage. Excluding them biases the analysis since such missiles are included in the "before-*Patriot*-arrived" case. Using all of the missiles that landed in the area of Tel Aviv and Haifa after the *Patriots* arrived increases the number from Postol's 14-17 to 24. Using the corrected numbers of damaged apartments, including the damaged ones in Haifa, results in a ratio of the "after-*Patriot*-arrived" case compared to the "before-*Patriot*-arrived" case of 0.82 per missile for casualties and 1.75 per missile for damaged apartments. These numbers provide much less food for thought.

Another methodological problem is Postol's inclusion of Haifa in his analysis. One would expect that the missiles aimed at Haifa, a much smaller and more irregularly-shaped city than Tel Aviv, would have inflicted less damage and caused fewer casualties than the missiles which were aimed at Tel Aviv. The actual war experience bears this out. But the percentage of missiles aimed at Haifa in the "before-*Patriot*-arrived" case is different than the percentage in the "after-*Patriot*-arrived" case. A logical basis does not exist for deciding how to prorate Haifa-targeted missiles relative to those aimed at Tel Aviv. This entire issue is easily avoided by analyzing only those missiles that were aimed at Tel Aviv (see Table 5--actual *Ma'ariv* chronology). But regardless of the case used, it is clear that the evidence from the attacks on Israel does not support any hypothesis that the *Patriot*'s use increased the number of casualties or damage.

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5. *Ibid*, p. 145.

APPENDIX III:
CHRONOLOGY OF LONG-RANGE MISSILE ATTACKS DURING THE PERSIAN GULF WAR

INTRODUCTION

What follows are three chronologies of the long-range missile attacks that occurred during the Persian Gulf War. The first is an overall chronology intended to permit one to see the general scope of the missile attacks, especially from the point of view of the Iraqi effort. The other two chronologies are more detailed and separately cover the theaters of the missiles attacks (Israel and Saudi Arabia plus the other Gulf States).

The chronologies are based on a chronology constructed by the author using the excellent coverage of the Gulf War by the *Los Angeles Times*. This chronology was then compared with a chronology published by Bermudez and one published by the Israeli newspaper *Ma'ariv* covering only the attacks on Israel.[1] These chronologies generally agreed with each other but where they differed the author relied on his judgment to produce the final chronology. While the author believes that these chronologies are the most comprehensive and accurate published to date, they should not be taken as the "last word" on this subject.

As stated in the text, it is estimated that between 86 and 91 Iraqi missiles were launched. Of these, 82 (some chronologies cite 81 or 83) missiles hit in or near the target countries (see Table 1). Thirty-nine landed in Israel, with 30 aimed at Tel Aviv, 6 aimed at Haifa, and 3 targeted the nuclear reactor at Dimona. Forty-one missiles landed in Saudi Arabia, of which 17 were aimed at Riyadh, 16 at Dhahran, 7 in the area of King Khalid Military City-Hafar Al Batin, and one at Al Jubayl. One each were aimed at Bahrain and Qatar.

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1. Joseph S. Bermudez Jr. "Iraqi Missile Operations During 'Desert Storm'--Update," *op. cit.* and table from March 29, 1991 issue of *Ma'ariv* reproduced in the April 16, 1991 Congressional testimony of Theodore A. Postol (see Appendix II).

The exact number of missiles which caused significant damage on impact is hard to determine. There appears to have been 13 which resulted in major damage in Israel--9 in Tel Aviv and 4 in Haifa. Six missiles appear to have caused major damage in Saudi Arabia--4 in Riyadh, 1 in Dhahran, and 1 in Hafar Al Batin.

The *Patriot* anti-missile system was used to intercept 47 missiles. It cannot be determined specifically which 47 missiles were involved, and in the detailed chronologies which follow, the use of the *Patriot* is mentioned only where it seems particularly relevant. Postol, in his work, has indicated that 17 of the intercepts occurred over Israel and 30 over Saudi Arabia.[2]

Other chronologies have used the date of the missile attacks as the means of organizing the attacks. However, most of the attacks occurred at night. By arranging their chronologies in this way they separate attacks that occurred during the same night but happened in the evening and the morning and at the same time combine attacks that occurred on the morning and evening of the same day. To avoid this, the chronologies in the current work are organized from noon of one day to noon of the following day and, in addition, it is also indicated which missiles were launched in salvos. In all cases local time was used which during the war was two hours ahead of Greenwich Mean Time (GMT) in Israel and three hours ahead of GMT in Saudi Arabia, Iraq, Qatar and Bahrain.

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2. Postol, "Lessons from the Gulf War PATRIOT Experience," *op. cit.*, p. 136.

GENERAL CHRONOLOGY OF LONG-RANGE MISSILE ATTACKS THE PERSIAN GULF WAR

[NOTE: Missiles launched in the same 24-hour period (from noon of one day until noon of the following day) are grouped together below.]

DATE	TIME OF DAY	TARGET NATION	TARGET	NO. OF MISSILES
{Jan 18, 1991	A.M. [Night]	Israel	Tel Aviv	6}
{Jan 18, 1991	A.M. [Night]	Israel	Haifa	2}
Jan 18, 1991	A.M. [Night]	Saudi Arabia	Dhahran	1
Jan 19, 1991	A.M. [Just after sunrise]	Israel	Tel Aviv	5
Jan 20, 1991	P.M. [Night]	Saudi Arabia	Dhahran	3
Jan 21, 1991	A.M. [Night]	Saudi Arabia	Riyadh	4
Jan 21, 1991	A.M. [Night]	Saudi Arabia	Dhahran	3
Jan 21, 1991	P.M. [Night]	Saudi Arabia	Dhahran	1
{Jan 22, 1991	A.M. [Just after sunrise]	Saudi Arabia	Riyadh	2}
{Jan 22, 1991	A.M. [Just after sunrise]	Saudi Arabia	Dhahran	3}
Jan 22, 1991	P.M. [Night]	Israel	Tel Aviv	1
{Jan 23, 1991	P.M. [Night]	Israel	Haifa	1}
{Jan 23, 1991	P.M. [Night]	Saudi Arabia	Riyadh	2}
{Jan 23, 1991	P.M. [Night]	Saudi Arabia	Dhahran	2}
{Jan 23, 1991	P.M. [Night]	Saudi Arabia	K.K.M.C.*	1}
{Jan 25, 1991	P.M. [Night]	Israel	Tel Aviv	6}
{Jan 25, 1991	P.M. [Night]	Israel	Haifa	1}
Jan 25, 1991	P.M. [Night]	Saudi Arabia	Riyadh	2
Jan 26, 1991	A.M. [Night]	Saudi Arabia	Dhahran	1
Jan 26, 1991	P.M. [Night]	Saudi Arabia	Riyadh	1
Jan 26, 1991	P.M. [Night]	Israel	Haifa	1
Jan 26, 1991	P.M. [Night]	Israel	Tel Aviv	3
Jan 28, 1991	P.M. [Night]	Saudi Arabia	Riyadh	1
Jan 28, 1991	P.M. [Night]	Israel	Tel Aviv	1
Jan 31, 1991	P.M. [Night]	Israel	Tel Aviv	1
Feb 2, 1991	P.M. [Night]	Israel	Tel Aviv	1
Feb 3, 1991	A.M. [Night]	Saudi Arabia	Riyadh	1
Feb 3, 1991	A.M. [Night]	Israel	Tel Aviv	1
Feb 8, 1991	A.M. [Night]	Saudi Arabia	Riyadh	1

DATE	TIME OF DAY	TARGET NATION	TARGET	NO. OF MISSILES
Feb 9, 1991	A.M. [Night]	Israel	Tel Aviv	1
Feb 11, 1991	P.M. [Night]	Israel	Tel Aviv	1
Feb 11, 1991	P.M. [Night]	Saudi Arabia	Riyadh	1
Feb 12, 1991	A.M. [Night]	Israel	Tel Aviv	1
Feb 14, 1991	A.M.[Almost Midday]	Saudi Arabia	Hafar Al Batin	2
Feb 16, 1991	A.M. [Night]	Saudi Arabia	Al Jubayl	1
{Feb 16, 1991	P.M. [Night]	Israel	Haifa	1}
{Feb 16, 1991	P.M. [Night]	Israel	Dimona	1}
Feb 19, 1991	P.M. [Night]	Israel	Tel Aviv	1
Feb 21, 1991	P.M. [Day]	Saudi Arabia	K.K.M.C.	2
Feb 21, 1991	P.M. [Night]	Saudi Arabia	K.K.M.C.	1
Feb 22, 1991	A.M. [Night]	Bahrain	Al Muḥarraq	1
Feb 23, 1991	A.M. [Night]	Saudi Arabia	Dhahran	1
Feb 23, 1991	P.M. [Night]	Israel	Tel Aviv	1
Feb 24, 1991	A.M. [Night]	Saudi Arabia	Riyadh	1
Feb 24, 1991	P.M. [Day]	Saudi Arabia	K.K.M.C.	1
Feb 24, 1991	P.M. [Night]	Saudi Arabia	Riyadh	1
Feb 25, 1991	A.M. [Night]	Israel	So. Israel	2
Feb 25, 1991	P.M. [Night]	Saudi Arabia	Dhahran	1
Feb 26, 1991	A.M. [Night]	Qatar		1

* King Khalid Military City

{ } Indicates salvoed missile attacks

DETAILED CHRONOLOGY OF LONG-RANGE MISSILE ATTACKS ON ISRAEL

[NOTE: Each entry covers a 24-hour period from noon of one day until noon of the following day.]

January 17-18, 1991:

The first missile attack of the War took place around 2:00 a.m., Israeli time. Eight missiles were fired--six at Tel Aviv and two at Haifa. Two of the missiles resulted in damaging impacts in Tel Aviv. One of these missiles landed in the Ezra neighborhood, fortunately in the only vacant lot in an otherwise densely built up area. This missile left a crater 60 feet across and 20 feet deep. One of the missile engines came down separately hitting an apartment, narrowly missing several occupants. In Tel Aviv 68 people were injured; 668 buildings were damaged (of which 31 were destroyed), and in which 1,009 apartments were damaged (of which 45 were destroyed). In Haifa apparently both missiles resulted in damaging impacts. No one was injured but 100 apartments were damaged as well as 100 shops in a large commercial center. The total damage in Haifa was estimated at 11.4 million Shekels ($5.7 million US dollars).

January 18-19, 1991:

This attack, consisting of five missiles aimed at Tel Aviv, took place around 8:00 A.M., Israeli time. Two of the missiles seem to have resulted in damaging impacts. One landed in Tel Aviv proper, injuring 47 people, damaging 1,399 structures, in which 1,589 apartments were damaged, of which 46 were destroyed. The other missile hit outside Tel Aviv injuring no one but damaging 100 apartments. One of these two missiles hit and heavily damaged an underground shelter which 60 people had planned to use but at the last minute they had sought shelter elsewhere. Had they remained, most if not all of them would have been killed by the missile.

January 22-23, 1991:

This attack occurred around 8:30 P.M., Israeli time. One missile landed in Ramat Gan, in the Gush Dan region surrounding Tel Aviv. The missile was engaged by a *Patriot*, but the missile caused

heavy damage nevertheless. It apparently scored a direct hit on a two-story apartment house. Three people died from heart attacks, 96 were injured, 357 structures were damaged, of which 7 were destroyed, and in which 1,726 apartments were damaged of which 61 were destroyed.

January 23-24, 1991:

This attack occurred around 10:05 P.M., Israeli time. One missile aimed at Haifa, and was engaged by *Patriot*. Despite a lack of injuries, there was an estimated 2.7 million Shekels ($1.2 million US dollars) worth of damage to 900 apartments.

January 25-26, 1991:

Attack occurred at night on the evening of January 25. Six missiles were targeted at Tel Aviv and one at Haifa. Apparently there were two damaging impacts in the Tel Aviv area. One missile struck a house in the Gush Dan region, killing one person--the first direct fatality from the missile attacks. This missile also injured 19 others, damaged 2,987 apartments, 2 buildings and 12 houses. The other missile struck Tel Aviv proper, injuring 25 people and damaging 1,169 apartments. In Haifa the missile injured no one, but damaged 700 apartments and 200 shops. The total damage in Haifa was estimated at 2.7 million Shekels ($1.3 million US dollars).

January 26-27, 1991:

This attack occurred at night on the evening of January 26. Three missiles were launched at Tel Aviv and one at Haifa. No damage or injuries resulted from any of the missiles.

January 28-29, 1991:

This attack occurred at night on the evening of January 28. One missile, apparently aimed at Tel Aviv, hit near the village of Dier Ballat on the West Bank. This village is near the Green Line, about 17 km short of the outskirts of Tel Aviv. No damage or injuries resulted from this attack.

January 31-February 1, 1991:

This attack occurred at night on the evening of January 31. One missile, apparently aimed at Tel Aviv, hit in the West Bank near the Green Line. There was no damage or injuries.

February 2-3, 1991:

One missile was launched at night on the evening of February 2 and another was fired on the morning of February 3 during the same night. Both landed somewhere in central Israel. No *Patriots* were fired in response. Neither missile caused damage or injuries.

February 8-9, 1991:

This attack occurred at night on the morning of February 9. One missile landed in the Gush Dan region near Tel Aviv. Twenty seven people were injured, 287 structures were damaged of which 7 were destroyed and in which 1,111 apartments were damaged. Of the 27 injuries, seven people had "chest pains" and six people had "panicked".

February 11-12, 1991:

One missile was launched into central Israel at night on the evening of February 11. It fell into an uninhabited area. There was no damage or injuries. On February 12 during the morning of the same night a missile hit the Gush Dan region near Tel Aviv. Seven people were injured, 375 homes and 436 apartments were damaged.

February 16-17, 1991:

Two missiles were launched at night on the evening of February 16. One missile landed in the Negev desert in southern Israel. Iraq announced that this attack employed the *Al-Hijara* missile and was directed at the nuclear reactor at Dimona. The other missile struck in northern Israel (presumably aimed at Haifa). Both missiles hit in open areas and caused no damage or injuries.

February 19-20, 1991:

One missile hit in central Israel at night on the evening of February 19 (presumably aimed at Tel Aviv). There was no damage or injuries.

February 23-24, 1991:

One missile hit in central Israel around 6:50 P.M., Israeli time (presumably aimed at Tel Aviv). There was no damage or injuries.

February 24-25, 1991:

This attack occurred at night on the morning of February 25. Two missiles hit in remote southern region (perhaps aimed at Dimona). There was no damage or injuries. These were the last missiles to hit Israel.

DETAILED CHRONOLOGY OF LONG-RANGE MISSILE ATTACKS ON SAUDI ARABIA AND THE OTHER GULF COUNTRIES

[NOTE: Each entry covers a 24-hour period from noon of one day until noon of the following day.]

January 17-18, 1991:

Night-time attack occurred on the morning of January 18. One missile, launched at Dhahran, was intercepted by a *Patriot*. There was no damage or injuries. This was the first-ever combat interception of a ballistic missile.

January 20-21, 1991:

Three missiles were launched at Dhahran around 9:50 P.M., Saudi time. Shortly after midnight of the same night four missiles were fired at Riyadh. A few hours later three more missiles were launched at Dhahran. Many *Patriots* were used to intercept these missiles. There were no injuries but there was damage to a building and a 10-foot deep crater was created in Riyadh.

January 21-22, 1991:

At night on the evening of January 21, one missile was launched at Dhahran. Near dawn of the same night five more missiles fired--two at Riyadh and three at Dhahran. No damage or injuries resulted but, despite a *Patriot* interception, an intact missile fuel tank fell on a street in Riyadh.

January 23-24, 1991:

At night on the evening of January 23, five missiles were launched--two at Riyadh, two at Dhahran and one at a site in "north-central" Saudi Arabia (perhaps King Khalid Military City). No damage or injuries resulted. It was initially reported that *Patriots* intercepted all of the missiles. However, it was later determined that since there was no *Patriot* coverage of north-central Saudi Arabia at that time, this missile simply must have missed its target.

January 25-26, 1991:

Two missiles were fired at Riyadh at night on the evening of January 25. Despite *Patriot* intercepts, one of the missiles smashed a wing of a government building killing one person and injuring 30 others. These were the first casualties in Saudi Arabia from the missile attacks. Ironically this fatality in Riyadh occurred only a few hours following the first fatality in Israel. On the morning of January 26 during the same night one missile was fired at Dhahran but there was no damage or injuries.

January 26-27, 1991:

At night on the evening of January 26, one missile was fired at Riyadh but there was no damage or injuries.

January 28-29, 1991:

At night on the evening of January 28, one missile was fired at Riyadh but there was no damage or injuries.

February 2-3, 1991:

At night on the morning of February 3, one missile was fired at Riyadh. Despite a *Patriot* interception, 29 people were injured and apartments were damaged.

February 7-8, 1991:

At night on the morning of February 8, one missile fired at Riyadh but there was no damage or injuries.

February 11-12, 1991:

At night on the evening of February 11, one missile fired at Riyadh. Two people in temporary housing near a university on the outskirts of the city were injured.

February 13-14, 1991:

On the morning of February 14, shortly before noon, two missiles were fired into northern Saudi

Arabia. In the town of Hafr Al Batin four people were injured and buildings were damaged. No *Patriots* were fired because none were in range.

February 15-16, 1991:

At night on the morning of February 16, one missile was fired at the town of Jubayl in northeast Saudi Arabia. The missile was intercepted by a *Patriot* and fell into the Gulf.

February 21-22, 1991:

During daytime on the late afternoon of February 21, two missiles were fired into northern Saudi Arabia (perhaps aimed at King Khalid Military City). Later at night on the evening of the same day an additional missile was launched at northern Saudi Arabia. Reportedly all of these missiles were launched from Baghdad. *Patriots* that had recently been relocated into northern Saudi Arabia fired at these missiles. This marked the first time that *Patriots* had been fired from northern Saudi Arabia. On the morning of February 22 during the same night, one missile was fired at Bahrain (perhaps aimed at the airfield at Al Manamah). This missile was intercepted by *Patriot* and did not strike the island.

February 22-23, 1991:

At night on the morning of February 23, one missile was fired at Dhahran but it exploded on its own in the air and the debris fell in the open desert.

February 23-24, 1991:

At night on the morning of February 24, one missile was launched at Riyadh; no damage or injuries were reported.

February 24-25, 1991:

In the early afternoon of February 24 during daytime, one missile was fired at northern Saudi Arabia (perhaps at King Khalid Military City). At night during the evening of the same day, one missile was fired at Riyadh. Neither missile caused damage or injuries.

February 25-26, 1991:

At night on the evening of February 25, one missile was fired at Dhahran. Due to a software error, a *Patriot* did not engage this missile. The missile hit a US barracks in Khobar (just outside Dhahran). Twenty eight people were killed and 97 others were injured. On the morning of February 26 during the same night, one missile was fired at Qatar; no damage or injuries resulted. This was the last missile launched during the War.

ABOUT THE AUTHOR

Over the past 19 years Mr. Jones has authored or coauthored thirty-four reports for various US government agencies including the Department of Defense, the Department of Energy, the Arms Control and Disarmament Agency, and the Nuclear Regulatory Commission. These reports have addressed the problems of the proliferation of advanced technologies in the Third World; the military applications and implications of new technologies; weapons selection and targeting; energy policy; and, overall nuclear strategy. He is also the coauthor of the book *Swords from Plowshares* and has written several magazine and newspaper OP-ED articles.

Mr. Jones currently consults on defense policy issues. Previously, he was a consultant to the Rand Corporation and a Senior Research Specialist at Pan Heuristics.